tech engineering news

april 1955

John F. Holt, class of '47

speaks from experience when he says . . .

"Expanding research and product development at U. S. Steel mean more opportunities for qualified engineers"

SINCE 1952, John F. Holt has been Assistant Superintendent of the Coke and Coal Chemicals Department at United States Steel's new Fairless Works in Morrisville, Pa. He started working at U.S. Steel—as a trainee—in 1947. That's a lot of progress in just five years. For in his present position, John is responsible for both the quality and the quantity of all coal chemicals produced at the Fairless Works – about 3,500,000 gallons of light oils per year. 190 hourly employees and 25 supervisory personnel report to him.

But John's case of rapid advancement is not unusual. U.S. Steel has always placed great emphasis upon its management training programs and has provided the kind of training that enables ambitious young engineers to take over responsible positions within a comparatively short time.

As one example, John feels that the opportunities in his own department are very promising at this time. He says, "Many important new concepts of modernization and expansion in such fields as the carbonization of coal and synthetic products are coming up every day pointing the way to extensive future developments. Well-trained engineers will be in a position to lead the way into these new areas of industry."

If *you* are interested in a challenging and rewarding career with United States Steel and feel that you can qualify, you can obtain further information from your college placement director. Or we will gladly send you our informative booklet, "Paths of Opportunity," upon request. Just write to United States Steel Corporation, Personnel Division, Room 1622, 525 William Penn Place, Pittsburgh 30, Pa.

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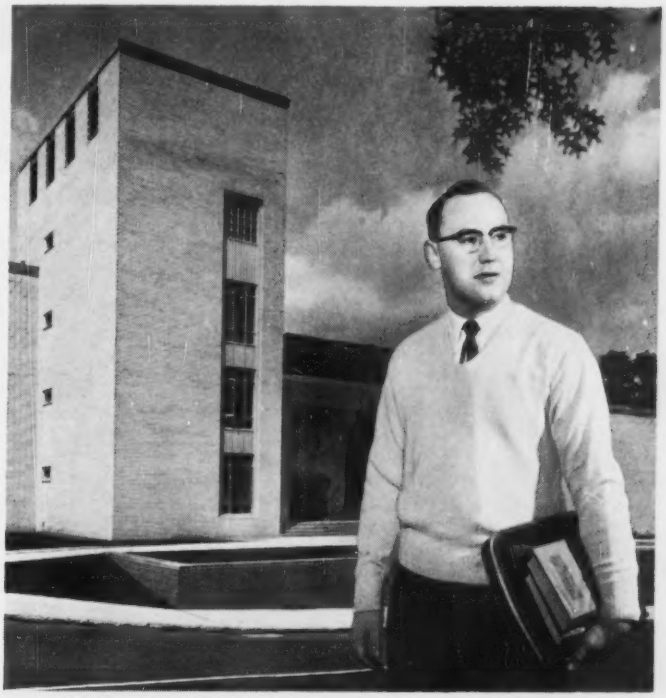
Jerry Loucks asks:

What sort of work would I do on my first assignment with Du Pont?



R. GERALD LOUCKS is currently working toward his M.S. in Chemical Engineering at Carnegie Institute of Technology. Jerry has served as president of his student chapter of A. I. Ch. E. and participated in intramural sports—besides finding time to play the trumpet in the R.O.T.C. and Kiltie bands. Right now, Jerry is giving a lot of thought to the selection of an employer.

CHARLES W. LOUNSBURY, Jr., worked at Du Pont's Chambers Works for three summers before he received his B.S. in Chemical Engineering from Rensselaer Poly. Inst. in 1940. Since then he has taken an M.S. from Carnegie Tech., and has been continuously employed on interesting assignments at various Du Pont plants. Today Charlie Lounsbury is Technical Superintendent of the Grasselli, N. J., plant of Du Pont's Grasselli Chemicals Department.

Charlie Lounsbury answers:

There is a great variety of first assignments at Du Pont, Jerry, depending on a man's field of training and the general area of work he has selected. For example, I understand you're interested in plastics, and you might start in *development work* on plastics, as I did. I worked with a team of more experienced engineers to increase the capacity of equipment used in producing "Lucite" acrylic molding powder. This was a natural prelude to my next major assignment, where I acted as a liaison between Du Pont's *Design Division* and the plant group—on the design of a new plant for making another form of "Lucite" plastic.

Or take *research work*. Here a new man is generally assigned to minor research problems until he becomes familiar with the general features and requirements of an industrial research program.

A young man interested in *sales* may start in a plant or laboratory dealing with the products he will later sell; or he may join a group of trainees to learn selling techniques right from the start.

A man aiming for *production supervision* may first spend a year or so in laboratory or plant development work. Or he may start as an operator—in a plant producing nylon or "Dacron" polyester fiber, for example. In this way he obtains firsthand knowledge of his process, and establishes a bond of mutual respect with the men he'll be working with on his major assignments later.

In general, Jerry, a man is chosen for a specific job within the scope of his major field of study. His first assignment is intended to help him make the best use of his abilities as promptly as possible.

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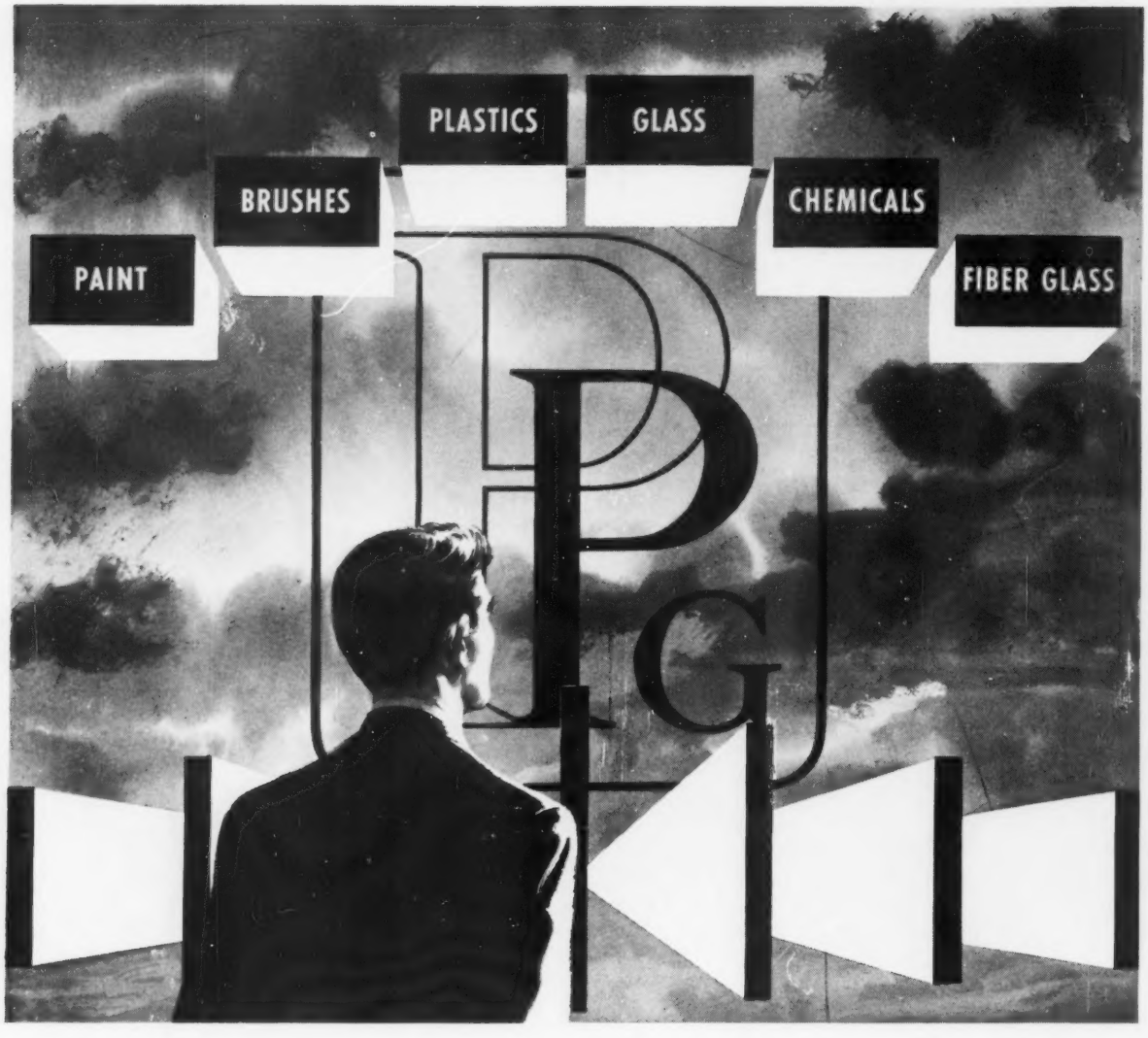

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MISSILE SYSTEMS

Research and Development

Physicists and engineers at Lockheed Missile Systems Division are engaged in a group effort covering virtually every field of science.

Missile Systems Division scientists and engineers discuss a new missile systems concept in light of tactical requirements. Left to right: Dr. H. H. Hall, nuclear physicist; I. H. Culver, systems development division engineer; Dr. R. J. Havens, research scientist; W. M. Hawkins, chief engineer; Dr. Ernst H. Krause, nuclear physicist and director of research laboratories; S. W. Burriss, experimental operations division engineer; Ralph H. Miner, staff engineering division engineer; and Dr. Eric Durand, nuclear physicist.

Continuing developments are creating new positions for those capable of significant contributions to the technology of guided missiles.

Lockheed

MISSILE SYSTEMS DIVISION

research and engineering staff

LOCKHEED AIRCRAFT CORPORATION • VAN NUYS, CALIFORNIA

tech engineering news

April 1955
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FRONTISPIECE

War

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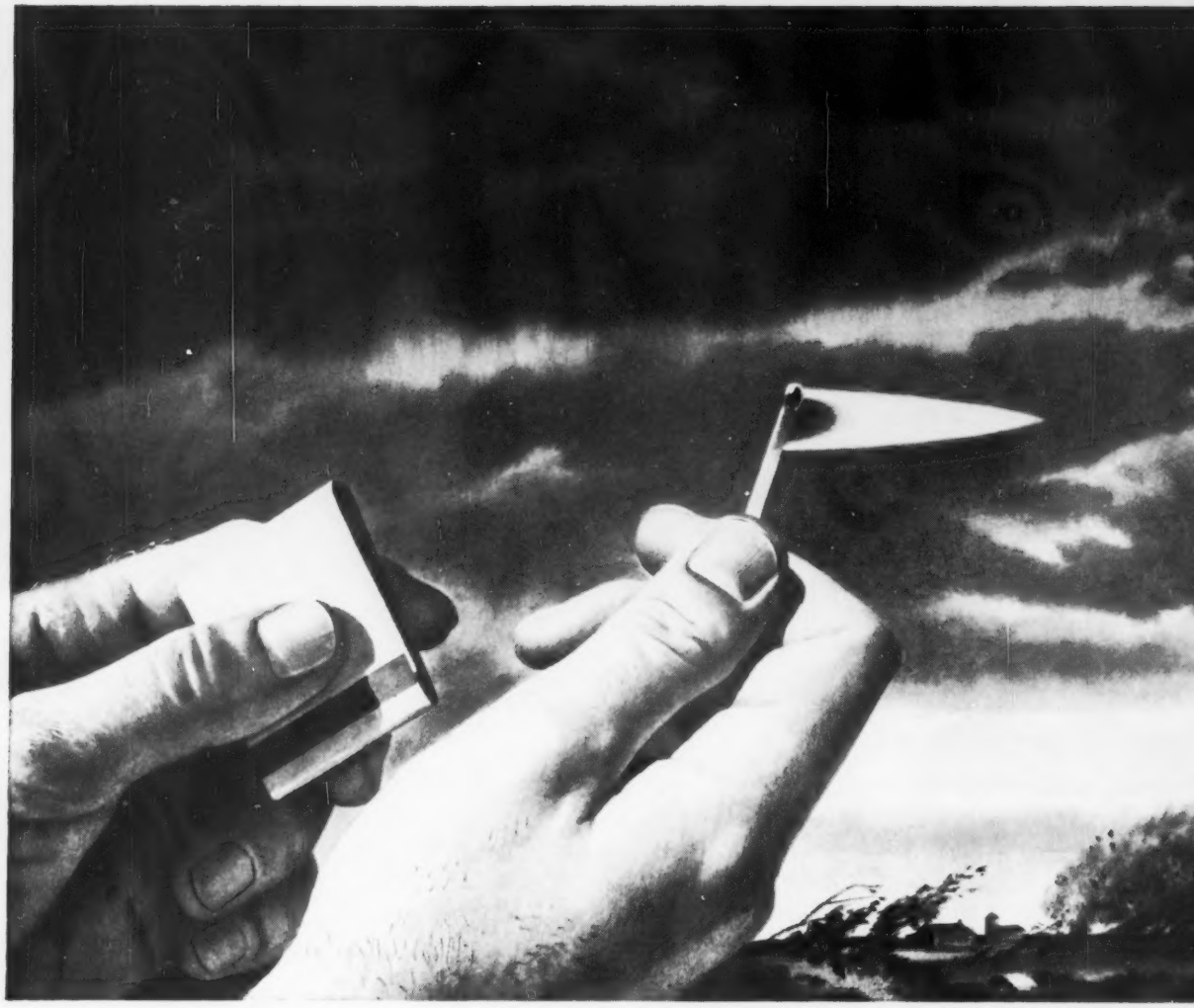

Bendix JET IGNITION

THE tough job of lighting a match in a tornado will give you some idea of the problem of firing a jet engine on the ground. Even more difficult is refiring the engine in flight should a flame-out occur—especially at high altitude.

Up there you not only have to reckon with low-volatility fuel but with rarefied air rushing through your engine at super-hurricane speed. Here, you can be certain, is a mixture that violently resists igniting!

Our Scintilla division at Sidney, N.Y., developed a special ignition system with the answer: a super-spark hot enough to fry a rock and of sufficient duration to fire and refire jet engines quickly. It has worked so successfully that, today, Bendix-Scintilla† Jet Ignition Systems have been selected as standard equipment by most of the leading jet engine manufacturers.

Nation's Foremost Source

Bendix-Scintilla is known to engine people everywhere as the nation's top source of supply for ignition equipment. Most military planes rely on our ignition, and we doubt if you can ride on a commercial airliner that isn't sparked by Bendix-Scintilla. Your power lawn mower, farm or garden tractor or outboard motor may have one of our many types of magnetos developed for such applications. Leading automotive manufacturers experimenting with turbojet engines in passenger cars, trucks and buses are using Bendix-Scintilla Jet Ignition.

Continual research and years of practical field operation have fitted us to anticipate and solve ignition problems; and that's why engine manufacturers, seeking advice, talk to Bendix-Scintilla people.

. . lights matches in man-made tornadoes!

This chapter is part of the over-all story of Bendix Aviation Corporation, a story of successful work in developing and making nearly a thousand different products for scores of basic industries. No doubt some of our products can contribute to your business by improving your operation and cutting costs. Why not write on your company letterhead for the interesting digest "Bendix and Your Business."

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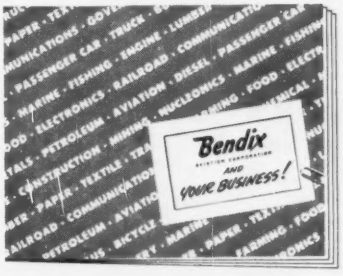

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automatic photoelectric ozone detector

by D. F. Shrader, '60

An automatic photoelectric instrument for continuous measurement of the ozone in the earth's atmosphere at low altitudes has been developed at the National Bureau of Standards. The system makes use of the optical absorption characteristics of ozone in certain ultraviolet spectral bands. It is expected that the development, which can determine ozone concentrations of a few parts per billion, will provide valuable information on air-mass movement and other weather phenomena. It is now being set up for use in a study of the Los Angeles smog problem. Other possible applications include the correlation of the visible deterioration effects of ozone on rubber with accurate measurements of ozone concentration in the atmosphere.

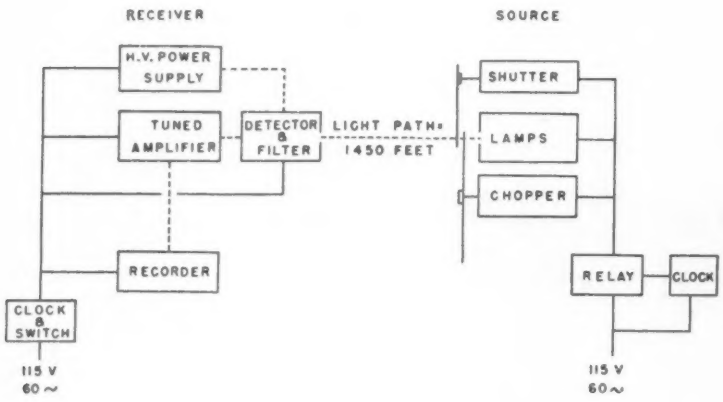
Ozone is normally produced in significant amounts only at high altitudes in the stratosphere. Here short-wave ultraviolet radiation from the sun causes photochemical dissociation of the oxygen molecule, and the oxygen atoms recombine to form ozone. Because ozone is an active oxidizing agent, the presence of organic particles in the atmosphere, together with the effects of long-wave solar radiation and increased temperature at lower altitudes, results in the destruction of most of the ozone molecules below heights of 15 to 18 km under normal conditions of atmospheric circulation. Thus, any appreciable quantity of the gas found at the surface of the earth must have been transported there by some means. Diffusion is slow and hence for the lower altitudes may be disregarded. Therefore, any ozone transportation at a rate sufficient to upset the static balance at the surface of the earth must be due to general large-scale air-mass movements associated with cyclonic and anticyclonic conditions, together with local air circulation resulting from thunderstorms and the like. This fact makes ozone concentration measurements of value in studying weather phenomena.

Ozone is an important constituent of the atmosphere because of its protective effect in absorbing short-wave solar radiation, but it is also highly deleterious to rubber and related organic products. Interest in the deteriorating effect of ozone on rubber materials has increased greatly in recent years with the development of new synthetic elastomers having varying degrees of ozone resistance. Although ozone is only one of several agents influencing the deterioration of rubber materials under the complex conditions of exposure to weather, it frequently proves to be the most severe. Simple methods for accurate measurement of its concentration have been urgently needed.

While various chemical methods for the measurement of ozone have been suggested or devised, most of these require close attention and give results which are an average over an interval of time. The apparatus developed makes possible a physical method based on the strong absorption characteristic of ozone in the spectral region centered between 2,500 and 2,600A (Hartley band). Using this spectral absorption, changes in the amount of ozone in the air are determined as a function of variations in the energy received at a detector from an ultraviolet source.

In the present setup, a steady source of ultraviolet energy is placed approximately 1500 feet away from, and directed at, a sensitive photoelectric detector. A bank of five commercial low-pressure mercury arc lamps is used as the energy source. The source is equipped with a glass tube that absorbs the 1,847A emission line of the lamps but transmits the 2,537A line and others of longer wavelength. In order to eliminate as far as possible the effect of other sources

Figure 1. Block diagram of the automatic photoelectric ozone detector. The device makes use of the strong optical absorption characteristics of ozone in certain ultraviolet spectral bands. A time-controlled mechanism changes three glass filters between the lamps and the detector so that radiant energy from the lamps is separated into bands primarily at wavelengths 253.7, 365.5 and 405.0 millimicrons. From the ratios of the deflections for the different spectral regions, it is possible to determine ozone concentration down to several parts per billion.



12 of the basic industries in which Bendix products play a vital role

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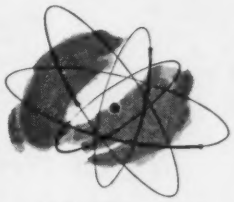
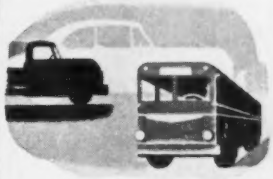
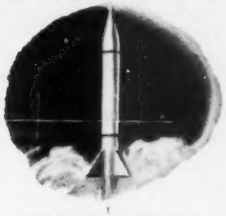


ATOMIC ENERGY



AUTOMOTIVE

AVIATION



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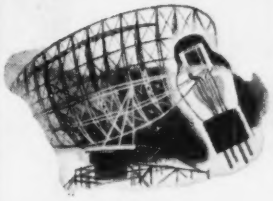
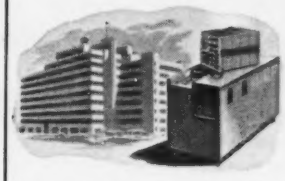


RADAR



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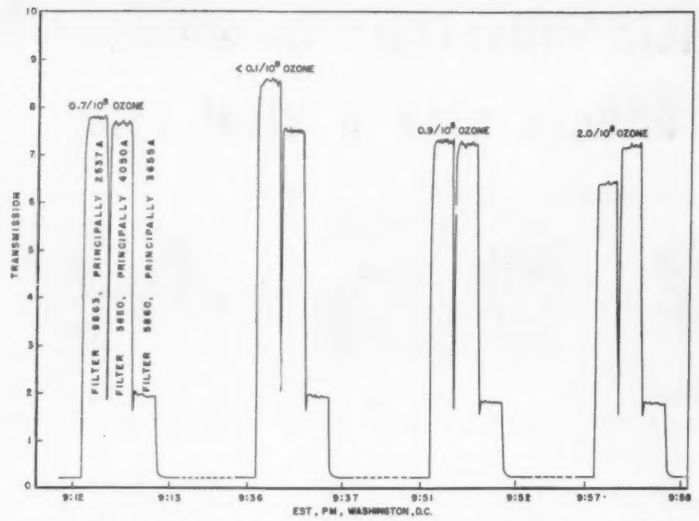


Figure 2. Sections of a recorder tracing made with the NBS automatic photoelectric ozone detector. The record shows the fluctuations in ozone concentration at Washington, D. C., on April 3, 1953.

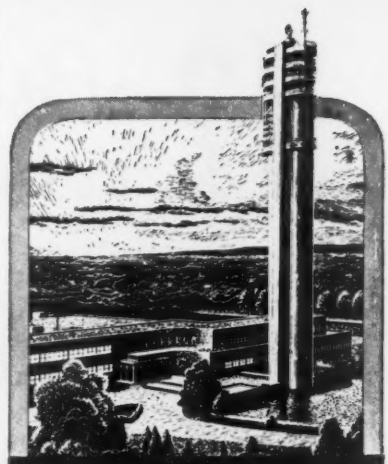
of light that might fall upon the photodetector, the radiant energy from the source is modulated at 510 cps. This is done by means of a synchronous rotating sector disk driven at 1800 rpm.

At the detector station the modulated light beam is picked up by a 1P28 photomultiplier connected with a tuned amplifier and recorder. A special photometer unit contains a mechanism for automatically changing optical filters over the photomultiplier. A set of three glass filters is arranged on a disk, so that alternate readings are made at three regions within the spectrum. The first of these is at 2,537A, the second at 3,655 and the third in the blue region. Each filter is placed in front of the photomultiplier for 15 seconds, after which the filter disk is rapidly moved to a new position for the next filter in the series. The fourth filter position carries an opaque shutter. Hence, during each minute a complete series of measurements is recorded. In order to correct for any scattered radiation from surrounding city lights, the moon, or other sources that might reach the photodetector, a shutter is automatically interposed in the light beam for about 1 minute every 15 minutes.

By means of a timing clock, the source may be automatically turned on before a similar clock starts the receiving apparatus. Likewise, the clocks turn off the equipment at a prearranged time each night. As all the components are controlled by timing clocks, the equipment requires no personal attention during periods of operation. Only day-time servicing and noting of weather data are required.

As the radiant energy from the five source lamps is extremely low after being transmitted approximately 1500 feet, the modulated source and the tuned-circuit amplifier are required in order to eliminate the zero drift resulting from the variable dark current in the photomultiplier. The photomultiplier is commonly operated at about 70 volts per anode, which results in a voltage amplification of the detected signal of about 100,000. Following this, a tuned a-c amplifier (with a voltage gain of several thousand) is employed to improve the signal-to-noise ratio and to obtain sufficient voltage for operating a standard strip recorder.

Because of the sensitivity of the photomultiplier to voltage changes, a carefully regulated power supply is essential for precision work. The power supply used contains many of the circuit elements commonly employed in conventional units to keep the output voltage constant over a wide range of input voltage. As the



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electric load of the amplifier is relatively constant, little attention need be given to regulatory devices to cover load variations.

Because the outputs of low-pressure mercury-arc lamps are affected by their operating temperatures, large changes in temperature of the lamps used in the present apparatus are eliminated by enclosing the five lamps in a box. The radiation from the lamps emerges through a small quartz-glass window installed in one side of the box.

Selective scattering of radiation by the atmosphere has been neglected in the ozone measurements. However, the effect of this scattering is small, and any error resulting from it is much less than that caused by other erratic changes in the atmosphere. Furthermore, it is assumed that any scattering by dust particles is non-selective and therefore does not affect the transmission ratios on which the evaluation of ozone is based.

Absorption by various impurities in the atmosphere, such as smoke or other combustion or chemical vapors associated with industry or housing, produces errors of unknown magnitude. Hence, the method cannot safely be employed where any vapors having absorption in the ultraviolet spectrum (at the wavelengths of the mercury emission lines) may be intermittently present. Many chemical and combustion vapors are known to have high ultraviolet absorption. Chimney vapors from the burning of coal, for example, when blown into the light beam cause erratic recorder tracings.

For daylight operations, this instrument must be properly shielded from scattered sunlight. Radiations in the spectral region of 3,200A to 4,000A, which are present in sunlight, will overload the 1P28 photomultiplier and will make its modulated response non-linear. When better filters become available, it should be possible to confine the response to those wavelengths that are not present in sunlight. Daytime operation would then be as convenient as night-time use.

ENGINEERING WRITING

Here is an ideal way for the engineer or physicist with some aptitude for writing to enter the field of advanced electronics. In this relatively new and expanding area you can make immediate and effective use of your academic training while acquiring additional experience.

Hughes Research and Development Laboratories are engaged in a continuing program for design and manufacture of integrated radar and fire control systems in military all-weather interceptor aircraft. Engineers who produce the maintenance and operational handbooks for this equipment work directly with engineers and scientists engaged in development of radar fire control systems, electronic computers, and other advanced electronic systems and devices.

Your effort in the field of engineering writing through these publications transmits information to other engineers and technical personnel on operation, maintenance and modification of Hughes equipment in the field.

You will receive additional training in the Laboratories at full pay to become familiar with Hughes equipment. Seminars are conducted by publications specialists to orient new writers. After-hours graduate courses under Company sponsorship are available at nearby universities.

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SCIENTIFIC AND ENGINEERING STAFF

Culver City, Los Angeles County, California

Photograph above: Engineer-writer John Burnett (left) works with engineers John H. Haughawout (right) and Donald King to compile handbook information.

IBM news

FOR ENGINEERING STUDENTS

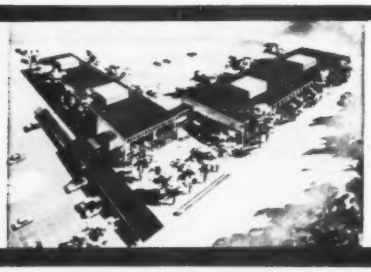
"IBM's a great place to work," says engineer now in his 8th year with the company

"Every year with IBM is more challenging than the last," says Max E. Femmer, Development Engineer at Poughkeepsie. "It was a tremendous satisfaction in 1952 to help develop IBM's outstanding 701 Electronic Computer. Today, our projects and our work are even more interesting. Both my wife and I think IBM is a wonderful company."
Mr. Femmer is Technical Administrator of the entire Electronic Data Processing Machine Development Program.

IBM Introduces 12 New Products in Year

The 12 new products introduced in the past 12 months dramatize IBM's continuing diversification.

Ranging from the versatile "Cardatype"—a major step forward in the simplification of office work—to the gigantic NORC, the most powerful electronic digital computer ever built, IBM's products serve *all* industries plus government and education.



IBM building 5 new labs

By early next year, 1500 members of IBM's engineering staff will be working in five new buildings now under construction (two sketched above). They will be built at Poughkeepsie, N. Y., and at Glendale, N. Y. overlooking the Endicott Valley.

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from the editor's notebook

MANAGING BOARD, VOLUME XXXVII

Carrying on next school year as the Managing Board of T.E.N. are four competent men who we believe will do a first-rate job in maintaining T.E.N.'s fine traditions. As General Manager will be this year's Editor-in-Chief, Allen Langord, '57. John Seeger, '56, our present Circulation Manager, will take over as Editor-in-Chief and Bob Koch, '57, will move up from Make-Up Editor to Managing Editor. Handling the books as Business Manager will be this year's Advertising Manager, Carl Estes, '57. The old Managing Board wishes the new four a successful year.

D.E.

NOTE ON THE M. I. T. NATIONAL INTERCOLLEGIATE CONFERENCE ON SELECTIVITY AND DISCRIMINATION IN AMERICAN UNIVERSITIES

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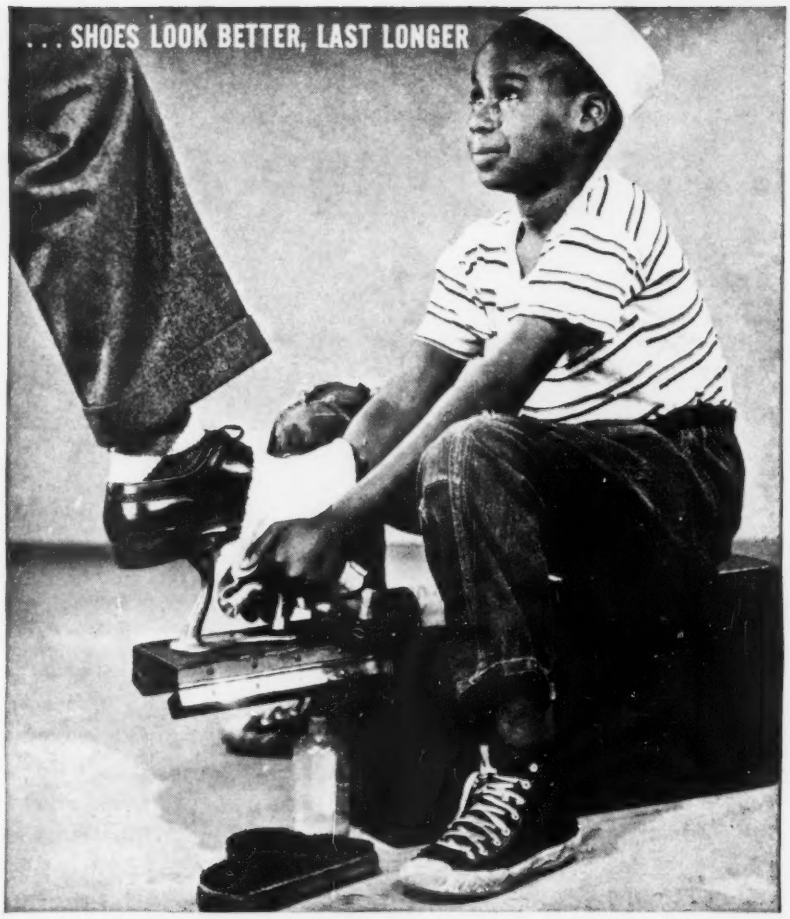

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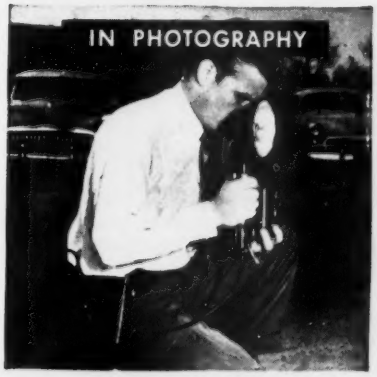

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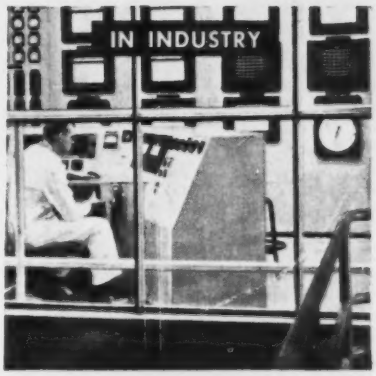

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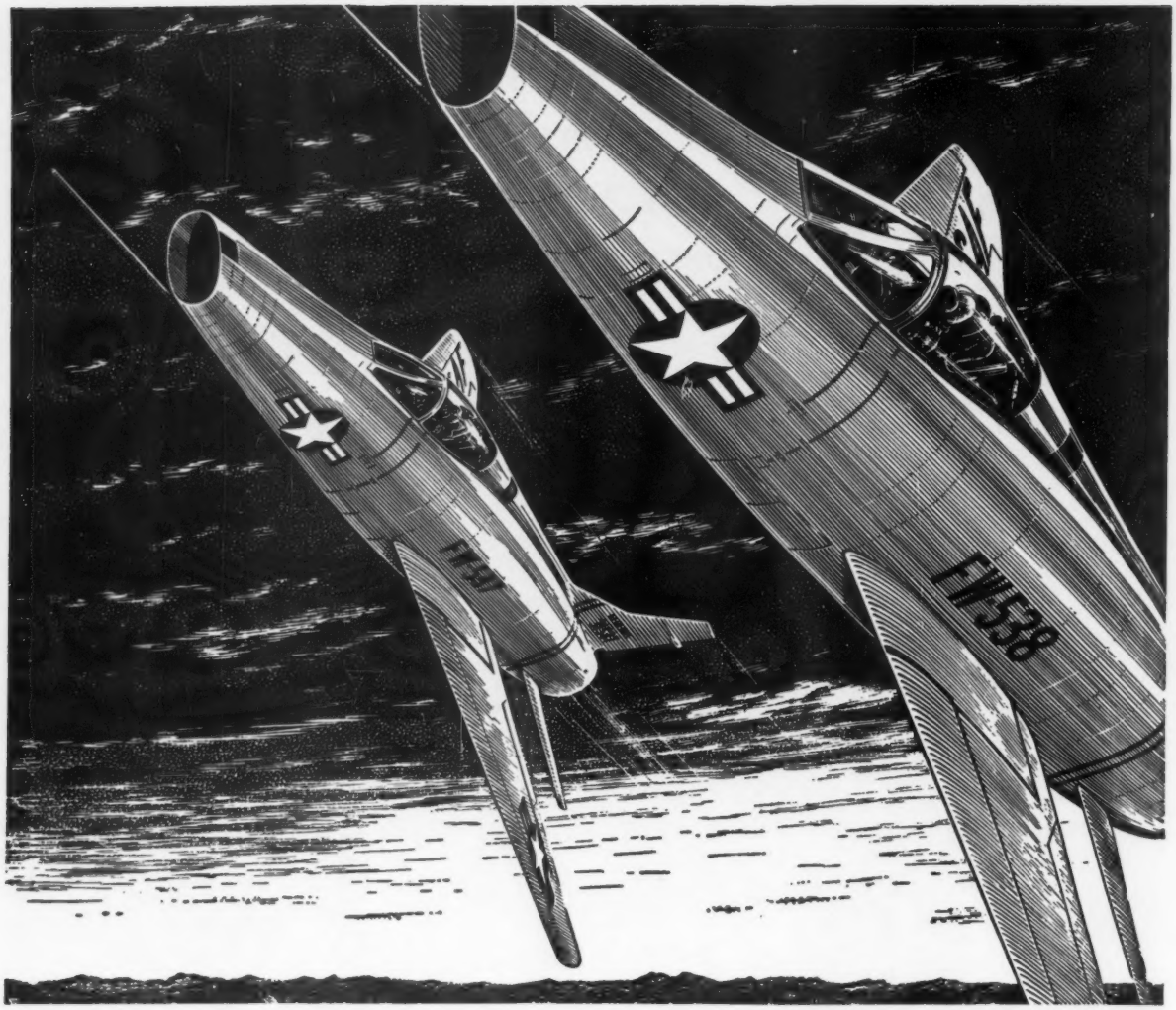

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The New Curriculum at the Massachusetts Institute of Technology

by John Morton Blum, Associate Professor of History

The New Curriculum at the Massachusetts Institute of Technology

The freshman who just left this office had arrived persuaded that his intended field of concentration, physics, demanded a special sense of awareness about and responsibility for the use of power in a troubled world. He was deluded, perhaps, only by his assumption that his was a special case, for physicists, after all, simply share the collective sense of responsibility, sometimes of guilt, that at this time penetrates the conscience of all perceptive men in the Western world. Ten difficult years have accentuated their realization that now indeed civilization—however banal the statement may seem—does hang in the balance when large decisions of public importance are made. And if a tragic miscalculation should occur, the culprit would obviously be not some holder of office but all those who created the environment informing him.

On this account, among others, the Massachusetts Institute of Technology began almost a decade ago to redesign the program in humanities required of all undergraduates. No more than any other institution has M.I.T. learned surely how to instill by classroom work some sense of irony, some compassion, some humility in students. But freshmen and sophomores must now in each semester attend general education subjects concerned with certain of the foundations of Western civilization, certain of the ideas that in modern times have beguiled Western man, certain of the issues that have puzzled him. Juniors and seniors must devote at least one subject in each semester to the humanities or social sciences, focusing their work within some one discipline they elect, be it economics, history, music or literature. No student, then, can avoid exposure to a range of educational experience intended not to constrict but to complement whatever technological curriculum he pursues.

So it is also with the new curriculum which the faculty without dissent has voted to establish—Course XXI: "Humanities and Technology." Like the other curricula at M.I.T., this is a form of technological education, but with this difference: students who choose to enroll in Course XXI will undertake a "double major", devoting 60% of their time to basic and advanced subjects in one field of science or engineering, 40% of their time to basic and advanced subjects in one of three fields of humanities. Students have long been permitted in Course XIV, "Economics and Technology", to combine mechanical or chemical or electrical engineering with economics. They will now be permitted to combine one of the engineering fields or, for example, mathematics or physics or biology with a sequence of subjects in American Industrial Society, or Political Thought and Institutions, or Philosophy and Literature. The Course XXI curriculum leads in four academic years to the degree of Bachelor of Science. It is arranged, furthermore, so as to permit a student in a fifth year to earn a second bachelor's degree with specific designation in the particular field of science or engineering he has been exploring. Course XXI, then, at the option of the student enrolled in it, can be either a terminal, four-year program providing a general education based upon science and engineering, or a five-year professional program enhanced by an incidence of general education at once broader than that customary for engineers and more integrated than that available in most colleges and universities.

Course XXI thereby permits experimentation on a small scale both with a new type of general education and a new kind of five-year engineering curriculum. Designed, as it is, to enrich the social consciousness of its students, it also offers excellent preparation for a career in medicine, law, business or public administration. Indeed, the characteristically rigorous standards of M. I. T.'s science and engineering, standards Course XXI students will have to meet, assure those of them who go on in law, business or government of an exceptionally thorough grounding in technology. Manifestly this grounding has signal meaning for men who are to become involved in exercising judgment about the affairs of an industrial society.

Although it will be several years before the structure of Course XXI can be seen entire, this structure appears now sufficiently firm so that what finally materializes should not vary significantly from what presently begins to emerge. The 60% of time allotted to science or engineering constitutes substantially the equivalent of three years of the technological work in any one of the existing curricula, all described in the M. I. T. catalogue.[1] Within the 40% of time devoted to humanities, Course XXI students will have to enroll in the humanities subjects prescribed for all freshmen and sophomores, subjects which draw upon materials from history, literature, philosophy and the arts. What remains to be explained, then, is the balance of the humanities program.

There will be no change in the freshman year, but two new electives, one in each term, will be made available for all freshmen and especially recommended for those interested in learning about the kinds of things Course XXI involves. These new subjects will be "Philosophy and the Scientific Methodology", an examination on an

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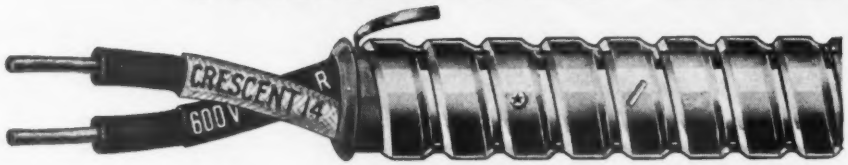

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elementary level of epistemological problems, and "American Character and Institutions", a study focusing, through the use of the social sciences, on the influence of technology and technological innovations upon the shaping of American life.

During their sophomore year students in Course XXI will have to begin to work in one of the three areas of study. Those selecting Philosophy and Literature will in the fall term enroll in an introductory subject in literature and in the spring in any one of several more advanced literature courses. Students selecting Political Thought and Institutions will in the fall study introductory economics, in the spring introductory political science. Students in American Industrial Society may follow this path or substitute for political science a second semester of economics.

During their junior and senior years students in Course XXI will have, depending upon their technological curriculum, either two or three free electives in humanities or social science. They will also have to take six semester subjects within the area of their choice. Those in Philosophy and Literature will select these six from subjects dealing with philosophy, literature, the history of science, and the history of ideas. So, for example, a student might fashion a program of these units: the history of science from the Greeks to Copernicus; the history of science from Galileo to the present; æsthetics; ethics; metaphysics; and the impact of the concept of evolution, of the concept of entropy, and of the uncertainty principle on philosophy and the social sciences.

Students in Political Thought and Institutions will select six subjects from courses on international relations and communications in a thermonuclear age, on the political process of economic growth, on comparative political institutions (with special reference to the cultural and economic foundations in diverse societies from which political institutions and habits grow). For one or two of these subjects, a relevant history course, such as "Europe: Industry and the State", or an economics subject such as "Labor Economics and Public Policy", might be substituted.

The American Industrial Society program includes subjects dealing with the impact of science on American thought; with social and intellectual responses to industrialism; with American literature; with the environment created by industrialism—the cities, buildings, works of art, both ugly and beautiful, that altogether involve the æsthetics of industrialism; subjects also on American economic growth, American industrial and technological history, the sociology of science, and the political significance of the clusters of power which have been produced by the industrializing and urbanizing of American life.[2] For one or two of these courses, an offering from those described for Political Thought and Institutions, or a relevant economics subject, such as "Money and Income", or a relevant subject in business administration, such as "Historical Studies in Innovation", might be substituted.

Most of the semester subjects in all three areas are obviously intended to focus continually (though not to the exclusion of other considerations) upon facets of the humanities and social sciences of demonstrable importance to techni-

cally trained men working in a technological society. This intention derives from the polarization of all education at M.I.T. around science and engineering. Course XXI, like every other curriculum, purposes to preserve for its students the special, ineffable attributes of the environment of the Institute, to sustain the toughness of training and develop the habits of mind that have long stamped M.I.T. graduates. These qualities have provoked generations of students to assert, in love and in jest rather than in dismay, that "Tech is Hell." These qualities have made industry, government and education seek them out, trust them and advance them.

The slanting of work in Course XXI toward science and engineering proceeds from still another objective—an attempt to achieve at last an integration within one college curriculum of technological and non-technological learning. To this end every Course XXI student during his senior year must enroll in a seminar designed to draw together the humanities subjects he has studied; he must also undertake a thesis or project contrived to utilize the experience afforded by these subjects in conjunction with the experience gained in his scientific or engineering subjects.

This integration has yet to be achieved; Course XXI students are still freshmen; time may demonstrate that the aspiration, however bold or meritorious, exceeds the reach of students and faculty alike. But the dimension of the objective makes the prospect of success only more enticing, and there is already evidence that the goal can be reached. A year ago an unusually able senior whose field of concentration was biology decided to compete for a Woodrow Wilson Fellowship for graduate work in history. By arrangement with the Department of Humanities, he took several special reading subjects in history. With the consent of the Department of Biology, he also wrote an interdisciplinary thesis, a study of the development of Walter Cannon's theory of homeostasis. In the opinion of both departments his performance was brilliant, characterized throughout by a sure grasp of biology, felicity of expression, provocative insights about creativity and the communication of ideas. He won the fellowship.

This is, moreover, not an isolated case, for in years past graduate students, enrolled in humanities minors consisting of three semester subjects on a level demanding no more virtuosity than the six subjects required in Course XXI, have demonstrated the feasibility of research in topics involving such variegated issues as the social and professional significance of associational activities of American engineers, the pattern of technological innovation in the electrical and automotive industries, the impact of changing technology on political decision-making, the implications for scientific creativity of political and military systems of security, and the institutional and intellectual obstacles to the communication of radically new scientific hypotheses. The young men who approached these difficult problems did not, of course, finally solve them, or even add significantly to the stock of knowledge that existed before they began to work. But they did add significantly to their own understanding of the professional environment in which they planned to live, of the processes by which their predecessors had forged change, of the stubbornness of tradition as well as the volatility of inspiration that characterizes science as well as other human activities. If the future senior in Course XXI can learn this kind of lesson from interdisciplinary work, that will be enough. He may in time accomplish more, may from the foundations of his early training move on to levels of interdisciplinary perception not yet in sight.

And so the A-bomb and the H-bomb and the X- and Y- and Z-bombs, the increasing social and industrial responsibilities of technically trained men, the desirability of experimentation in college education, and so, perhaps especially, the possibility of a break through the opaque curtain that has long separated technologists and humanists, give rise to Course XXI. This last particularly—exciting, essential, still elusive prospect that it is—can surely serve to counsel and sustain the efforts that it merits.

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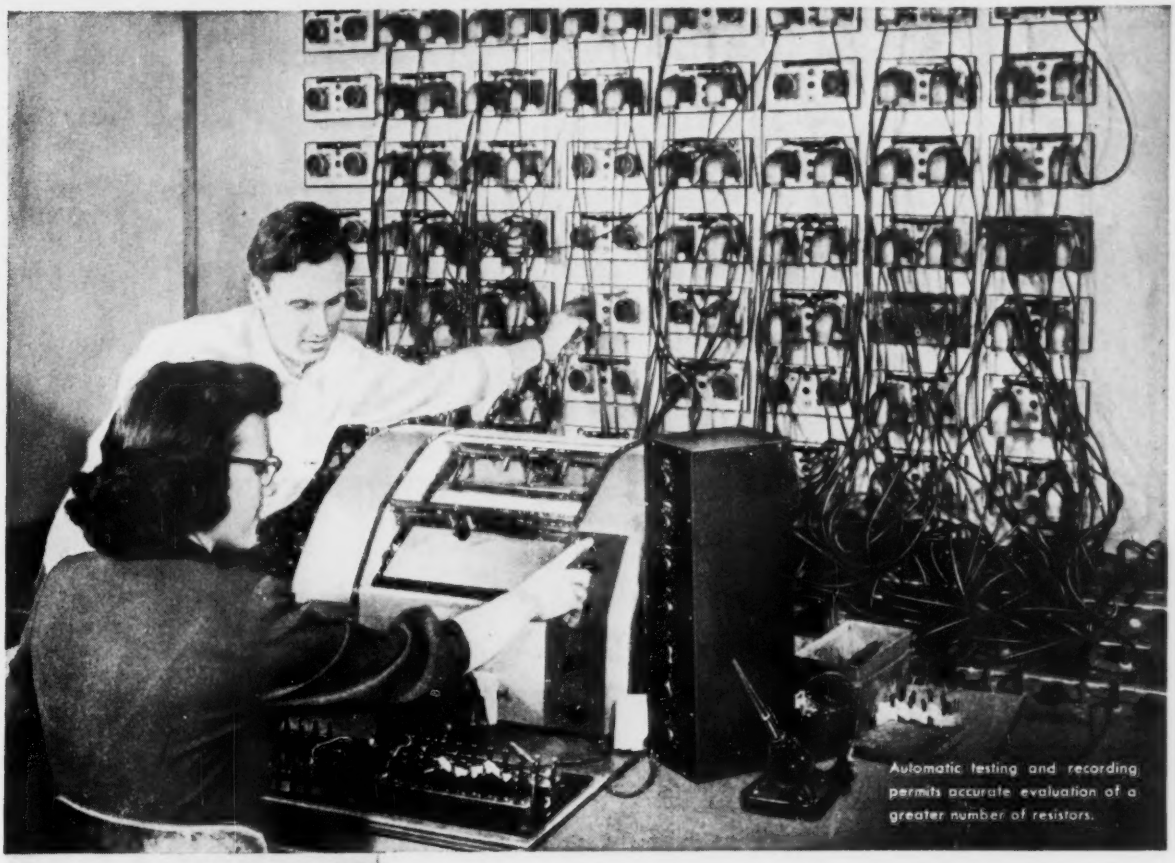

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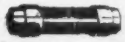

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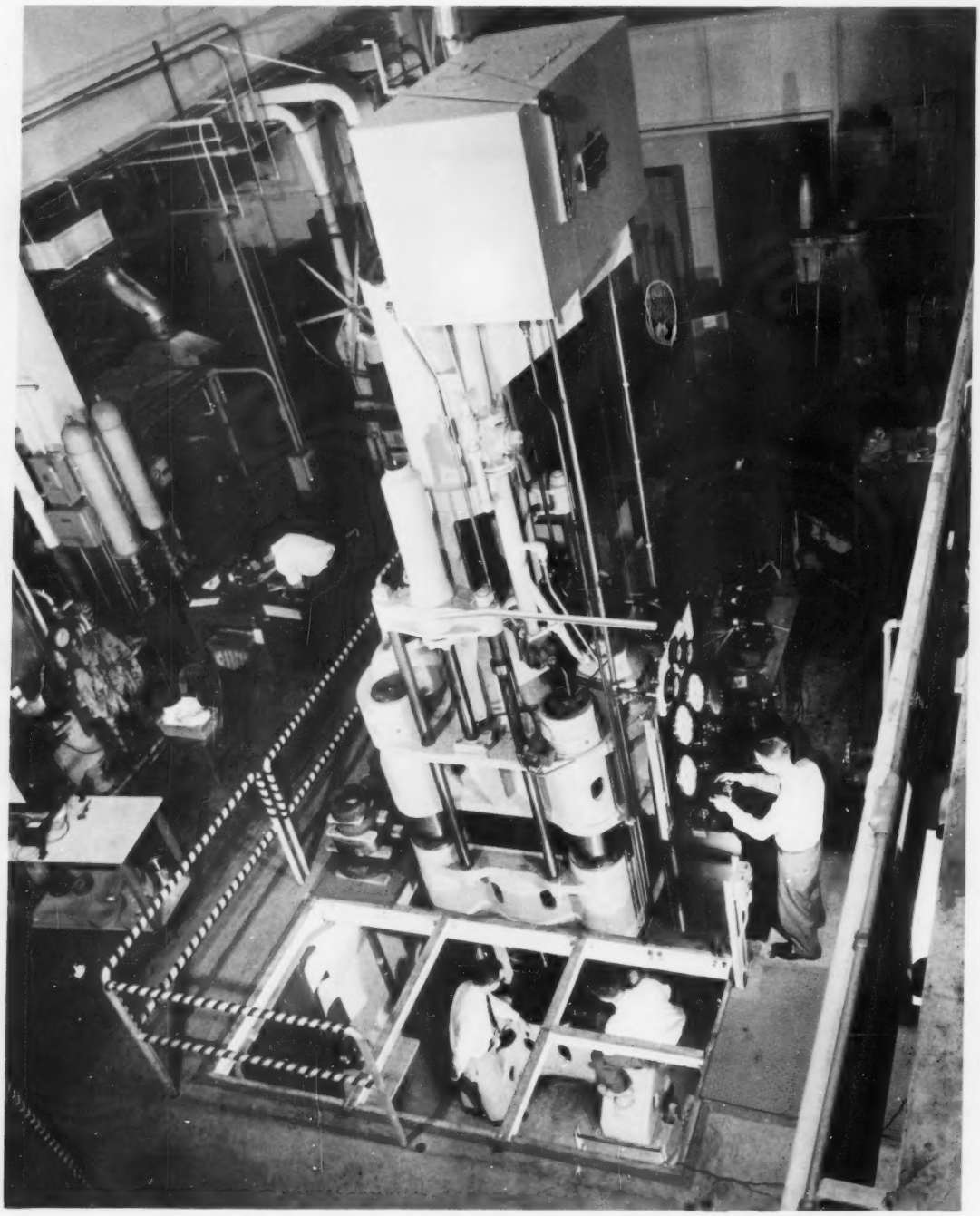

Man-made diamonds, the climax to a 125-year effort to duplicate nature's hardest and most glamorous substance, were displayed recently.

Scientists of the General Electric Research Laboratory exhitited tiny diamonds made from a carbonaceous material subjected to extreme pressures and temperatures. The largest stone measured 1/16 of an inch in longest dimension.

In announcing "one of the landmarks in man's search for knowledge about his world," they warned that "any conclusion we are about to make diamonds of a size and quality suitable for gem use is decidedly premature." Diamonds for jewelry must have special characteristics of size, color, and crystal perfection.

"On the other hand, if the present high cost of making diamonds by the G-E processes can be reduced, the primary application of man-made diamonds will probably be in industrial tools for cutting and polishing. Diamonds of any quality, regardless of size and color—including diamond dust —are useful in industry. The crystals are not 'imitation' diamonds or 'diamond-like.' Rather they are purely and simply diamonds, exactly the same as are taken from mines of the Belgian Congo and Brazil."

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According to the manager of the Laboratory's Chemistry Department, the diamonds were positively identified by x-ray inspection, chemical examination, and hardness tests. Under hardness tests, the G-E diamonds proved capable of scratching anything, even other diamonds.

Thus these diamonds are the first man-made substance to scratch other diamonds.

Making diamonds was the result of more than four years of intensive research by Laboratory scientists.

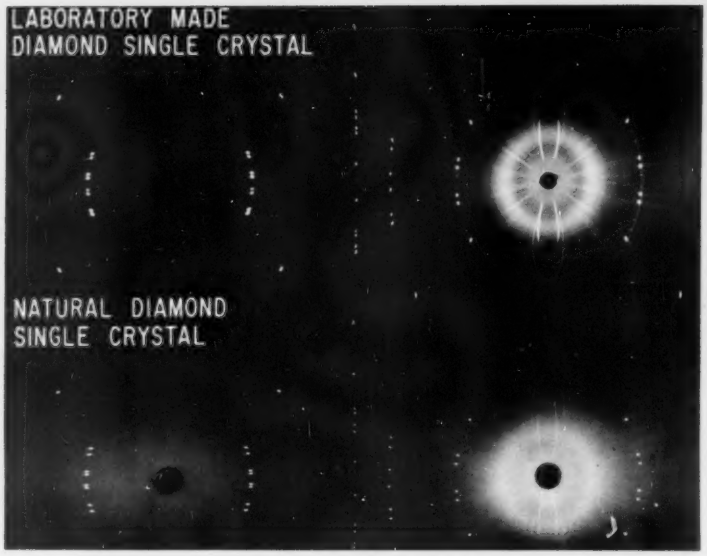
In the process, a carbonaceous compound was subjected for many hours to a measured pressure some 53,500 times greater than atmospheric (roughly 800,000 pounds per square inch). That run, in the Laboratory's new 1000-ton press, yielded a crystal nearly a sixteenth of an inch in longest dimension.

Of fundamental importance was the development of the "belt," a chamber enabling G-E scientists to maintain for the first time temperatures above 5000 degrees Fahrenheit at pres-

sures in excess of 1,500,000 pounds per square inch.

This pressure is roughly equivalent to the "squeeze" physical scientists have computed for points 240 miles beneath the earth's surface. Using this equipment, a process was developed that produces diamonds in a matter of minutes. The diamonds are smaller, but are often produced in solid clusters. Single runs have produced up to 1/10 of a carat.

To confirm the results two independent teams of scientists from other departments in the Laboratory have repeated the experiments, in each case with success. All in all, the various processes for making diamonds have been repeated successfully more than 100 times.



X-ray diffraction patterns of natural and man-made diamonds. Single crystal on the left; powder on the right.

Many of the first diamonds produced were deliberately destroyed during essential testing. For example, many crystals had to be burned to determine their carbon content.

X-ray examination is perhaps the most conclusive single test, because every crystal from common salt to precious jewel has its own distinctive x-ray "fingerprint," or diffraction pattern. It is easy to recognize the pattern of diamond because no other known material comes anywhere near matching it.

General Electric attaches great importance to the possibility of producing diamonds as a logical extension of its interest in hard cutting materials represented by cemented carbides.

The true status of previous attempts to make diamonds is difficult to determine with certainty. Principal claimants of success were a Frenchman, C. Cayniard de la Tour (1828); an English experimenter by the name of Hannay (1880); the French scientist H. Moissan (1894); and a British scientist, Sir Charles Parsons (1907-1920), who subsequently expressed doubt about his own results.

Repeated attempts by many researchers to reproduce the results claimed by these earlier investigators have failed, and careful analyses of existing records by reputable scientists have not confirmed any previous claims that diamonds were actually produced in the laboratory.

Certainly no sure method of repeatedly making diamonds has ever been announced before today.

In perfecting the long series of laboratory improvements in their struggles to achieve combined high pressure and high temperature, G-E scientists gained valuable help from nature, particularly from studies of diamonds found in Arizona meteorites.

Knowledge of pressures reached was gained by observing changes in the electrical resistance of bismuth, thallium, cesium, and barium-phenomena discovered by Dr. Percy Bridgman of Harvard University, world-renowned pioneer in high-pressure research.

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The development of a better means of measuring instrument bearing torque is but one of many Fafnir contributions to the ball bearing industry. The Fafnir Bearing Company, New Britain, Conn.

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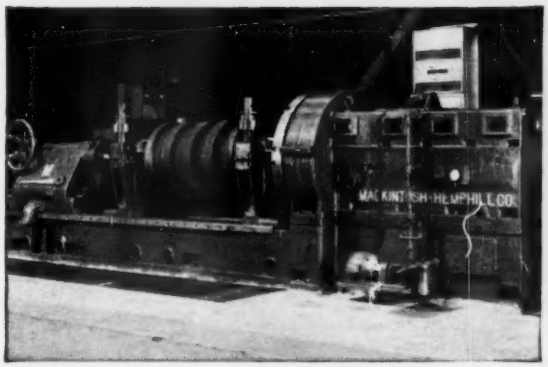

The engineers who designed this roll-neck lathe were faced with three problems. 1) To build a lathe that would cut finishing time as much as 75%; 2) To build a lathe that would give great accuracy and 3) To provide great load-carrying capacity as well. Their answer was this electronically-controlled mill roll lathe. To carry the 35-ton loads with a maximum runout of .0003 and still do the job quickly, they specified Timken® tapered roller bearings.

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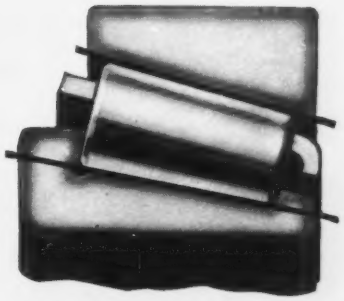

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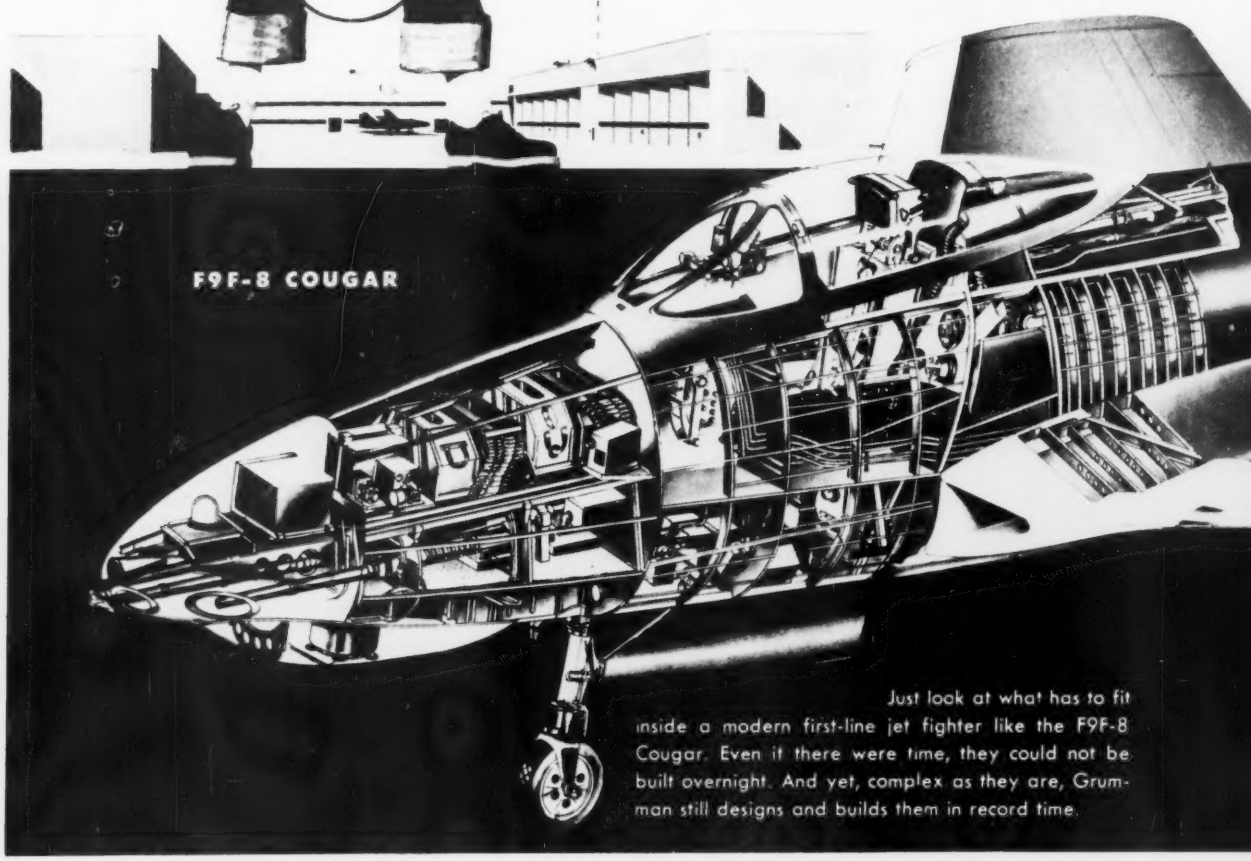

Just look at what has to fit inside a modern first-line jet fighter like the F9F-8 Cougar. Even if there were time, they could not be built overnight. And yet, complex as they are, Grumman still designs and builds them in record time.

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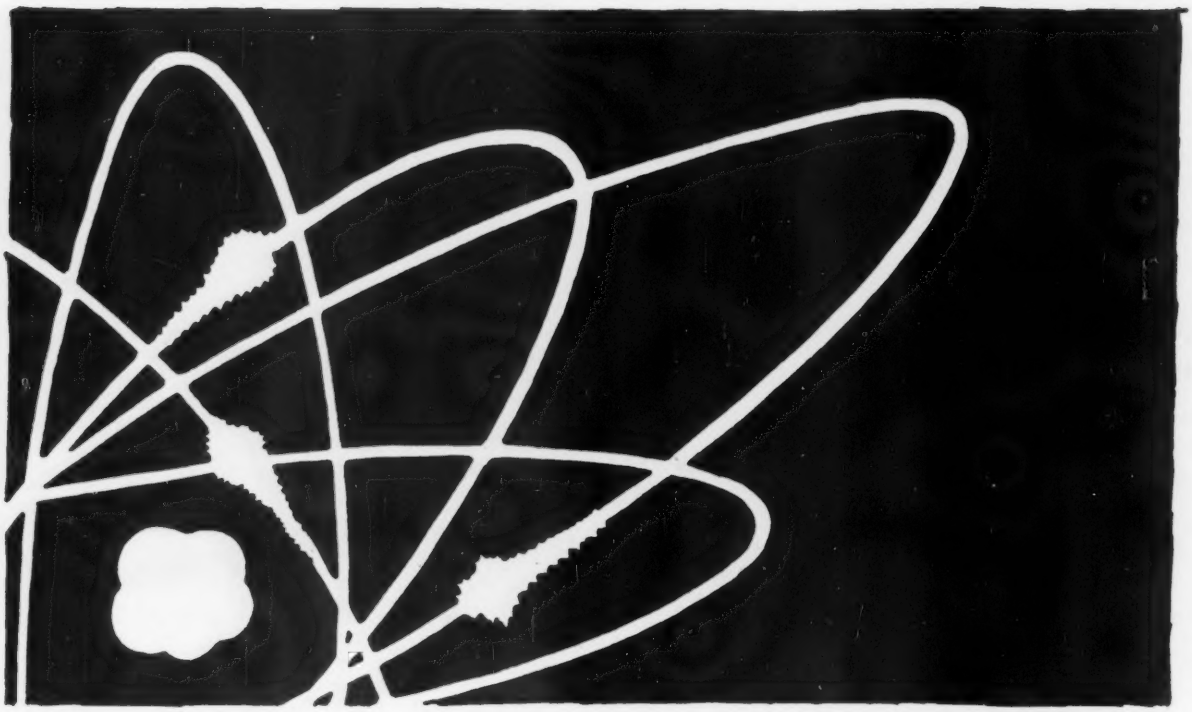
elementary particles II

by Malcolm MacLeod



In the previous article we saw how the search for the quanta of the nuclear force field led to the discovery of new particles called mesons. Up to 1947 two types of mesons were known: pions and muons. The muons were at first thought to be the particles whose existence was postulated by Yakawa to explain the forces existing between nucleons, but as more experimental evidence was gathered it gradually became evident that their properties were inconsistent with the properties deduced on the basis of nuclear theory. With the subsequent discovery of the pion, many of these inconsistencies were eliminated when the pion was substituted for the muon in the theory. Just when things began to look reasonably promising from the standpoint of explaining nuclear forces and these elementary particles, the experimentalists (as usual) came up with something brand new. In 1947 Rochester and Butler observed two V-shaped tracks in some cloud-chamber pictures of penetrating cosmic ray showers which they attributed to two new particles, to which they gave the names of "V-particles" (now known as and particles). In the following year Powell and co-workers observed in some nuclear emulsions a track they attributed to a "tau meson"; O'Ceallaigh observed a "kappa meson" in 1951, and so the story goes, each year adding more confusing experimental evidence. Table 1 gives a summary of the particles whose existence was reasonably well substantiated in January 1955.

The majority of these particles have been found by the use of nuclear emulsion techniques; the remainder of this article will be devoted to describing these techniques and what can be done with them. A "nuclear emulsion" consists essentially of grains of silver bromide dispersed in a gelatin support; the general idea is quite similar to the familiar photographic film, but with two essential differences. Ordinary film has one-tenth the density of silver that the nuclear plates have, and film has a thickness of roughly fifteen microns, whereas the nuclear emulsions vary in thickness from 25 microns to as much as 2000 microns.

The basic mechanism which renders the technique useful for investigation of elementary particle processes is that of energy transfer between an ionizing particle and the matter which it traverses; this energy goes into producing a photographic trace in the plate. As a high-energy charged particle traverses matter it is acted on by the electromagnetic fields of the atomic nuclei; in particular it is decelerated by these fields. The energy lost in the deceleration process appears as electromagnetic radiation ("bremsstrahlung") which can in turn bounce electrons out of the

atoms, leaving them free to wander about through the substance (silver bromide, in our case). Electrons can also be knocked out of the atoms directly by the particle as it goes through. In any case, the result of the passage of a particle through a silver bromide crystal is that a great number of electrons are released; these move about freely in the crystal until they come in contact with a "sensitivity speck" (a minute impurity center) where they are trapped at a lower energy level than exists in the rest of the crystal. A great many electrons collect at each impurity center, where they exert an electrostatic attraction on the mobile silver ions present in the crystal; these silver ions collect and form silver metal specks after being neutralized by the electrons. It is precisely these specks which render the grains "developable". When a developing agent acts on the emulsion it reduces an exposed grain to metallic silver, while leaving all unexposed grains untouched; a "fixing" agent dissolves the unexposed grains, thus leaving an image of silver specks behind. Upon examining the emulsion with a low power microscope the tracks of these particles may be seen.

The process is influenced by the rate at which the electrons are freed along the particle's track through the grain; that is, it depends on the velocity and ionization (energy loss per unit length) of the particle. If the ionization is plotted versus the velocity of the particle, it may be seen that the initial dE/dx goes inversely as v^2 and approaches a minimum at a velocity corresponding to roughly twice the rest energy of the particle. Beyond the minimum point dE/dx increases rather slowly and when the particle is located in this region it is said to be "minimum ionizing" and the corresponding track is called a "minimum." Minimum tracks are, of course, the most difficult to detect because the grain density is directly proportional to the ionization. Detection of minimum tracks presented quite a problem to research workers for a long time; finally emulsions were developed which would register these tracks properly. This was done by an English firm, Ilford Ltd., a few years ago. The main producers of nuclear emulsions, incidentally, are Eastman Kodak and Ilford, of which Ilford is preferred in most laboratories for their more uniform results.

There are three variables which may be used to characterize a particular track: grain density, scattering, and range. To measure the energy, the mass, or the momentum, two of these three variables must be known. The grain density, as the name implies, is simply the number of grains per unit length of a track at a given point on the track. This grain density is proportional to the mass and inversely proportional to the square of the velocity, so that it is easily seen that a fast, light particle will leave a very light track. This means that for a given energy an electron will leave a comparatively light track, a proton a comparatively heavy track, and mesons will fall between the two in grain density. The scattering which a track shows, i.e., the amount the track bends, is inversely proportional to the mass and the square of the velocity. Thus for an electron and proton of the same energy, the proton will

TABLE I

PARTICLE	SYMBOL	MASS (ELECTRON MASS UNITS)	DECAY SCHEME	HALF LIFE (SECONDS)
NEUTRINO	ν	< 0.05	—	—
ELECTRON	e	1.00	—	—
MUON	μ	206	$\mu^{\pm} \rightarrow e^{\pm} + 2\nu$	$2.1 \cdot 10^{-6}$
PI ZERO	π^0	266	$\pi^0 \rightarrow 2\gamma$ $\rightarrow e^{\pm} + e^{\mp}$ $\rightarrow \gamma + e^{+} + e^{-}$	$\sim 10^{-14}$
PION	$\pi^{\pm}$	273	$\pi^{\pm} \rightarrow \mu^{\pm} + \nu$	$2.8 \cdot 10^{-8}$
TAU MESON	$\tau^{\pm}$	965	$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{+} + \pi^{-}$ $\rightarrow \pi^{\pm} + 2\pi^0$	$5.0 \cdot 10^{-9}$
THETA ZERO	θ^0	960 - 970	$\theta^0 \rightarrow \pi^{+} + \pi^{-}$	$1.5 \cdot 10^{-10}$
THETA PLUS (MINUS)	$\theta^{\pm}$	~955	$\theta^{\pm} \rightarrow \pi^{\pm} + \pi^0$	$\sim 10^{-9}$
K PARTICLE	$K^{\pm}_{e3}$	~1000	$K^{\pm}_{e3} \rightarrow e^{\pm} + ? + ?$	$>> 10^{-14}$
K PARTICLE	$K^{\pm}_{\mu 2}$	920-960	$K^{\pm}_{\mu 2} \rightarrow \mu^{\pm} + \nu$	$\sim 10^{-8}$
K PARTICLE	$K^{\pm}_{\mu 3}$	~1000	$K^{\pm}_{\mu 3} \rightarrow \mu^{\pm} + ? + ?$	$>> 10^{-14}$
K PARTICLE	K_{N00}	~1400	?	?
PROTON	p	1836	—	
NEUTRON	n	1841	$n \rightarrow p + e^{-}$	21
LAMBDA ZERO	Λ^0	2182	$\Lambda^0 \rightarrow p + \pi^{-}$	$2 \cdot 10^{-10}$
LAMBDA PLUS (MINUS)	$\Lambda^{\pm}$	~2400	$\Lambda^{\pm} \rightarrow n + \pi^{\pm}$ $\rightarrow p + \pi^0$	$< 3 \cdot 10^{-10}$
Y ZERO	Y^0	~2800	$Y^0 \rightarrow ?^{-} + \pi^{+}$	—
Y MINUS	Y^{-}	~2800	$Y^{-} \rightarrow \Lambda^0 + \pi^{-}$	—

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show considerably less scattering than the electron. The third variable, the range, is simply the distance which the particle traverses before it loses all its kinetic energy and comes to a stop in the emulsion; it varies directly as the mass, the square of the energy, and inversely as the square of the charge. By means of the above three properties of the tracks, conservation of energy and momentum, the overall appearance of the events, and a strong faith in what one is doing, a large amount of information may be gleaned from these plates.

There are three phases gone through in utilizing the nuclear emulsion technique: exposure, processing, and scanning. We shall now look at these in detail.

In planning an exposure, there are a number of things to think about. If the particles being sought are energetic, their tracks will be long; since it is usually desired to have the particle stop in the emulsion, there are two ways of accomplishing this. The emulsions may be used mounted on glass plates (to give them the necessary rigidity) and exposed to the source of particles so that they enter the plate through one edge and travel through it laterally, coming to a stop in the same emulsion they first entered. The alternative to this is to form a "stack" of unmounted emulsions (sometimes termed "pellicles") so that a continuous sensitive volume of emulsion is formed. With this arrangement tracks may be followed through the stack from one emulsion to the next; this is in general an excellent means of tracking particles whose incident directions are not defined to within a narrow range of angles, as is necessary for the first method to prove its worth. Which of these two methods to use in a given case is decided mainly by what type of particle source the plates are to be exposed to, although the type of experiment also comes into consideration. There are two sources of particles in wide use today: the cosmic rays which bombard our planet continually, and the high-energy particle accelerators, such as the synchrotron, and cosmotron. Until 1948 only the first of these was utilized for the study of the new "strange particles", for it was not until that year that any high-energy accelerators produced artificial mesons. Since then, however, all of the particles have been produced artificially. For a cosmic ray exposure the obvious thing to do is use a stack, since there may be many related events; for an accelerator exposure, the method to be used depends largely on the particular experiment. For example, for a study of the secondaries from K particle decay, a stack is necessary since these particles are given off at random directions to the K in the center-of-mass system and have a great deal of kinetic energy, consequently a long range. On the other hand, for a study of the angular distribution of the protons given off when deuterons (heavy hydrogen nuclei) are made to disintegrate by means of bombardment by high-energy gamma rays all that is necessary is to know the angle at which the protons enter the emulsion, which may be done using plates, although admittedly a more accurate determination would require the use of stacks.

The processing of these emulsions is quite complex compared to processing a roll of film. The main factor to be taken into consideration is the thickness of the emulsions; because it is so great, it takes a rather long time for the processing solutions to diffuse into them. There are two other effects which worry the researcher; shrinkage and distortion. Shrinkage is due to dissolving the unexposed silver halide grains out of the emulsion; the gaps left where the grains were are filled by the gelatin which flows into them in the plastic state it is in during the processing. This effect may be counteracted by measurement of the shrinkage factor, which may be done by exposing the emulsions to a source whose tracks make a definite, known angle with them and then determining the path in the developed emulsion. The second effect is distortion, which is usually introduced through slippage of different emulsion layers (in one emulsion) over one another, thus introducing spurious "scattering". The amount of distortion may be estimated by observing "steeply dipping" tracks, i.e., tracks which plunge through the emulsion essentially perpendicular to the broad face. Other problems which complicate matters will perhaps be better understood if the development procedure is first outlined. The following is the processing procedure used at the M.I.T. Synchrotron Laboratory, and is representative of the manipulations involved.

If the emulsions are pellicles, they are mounted first on specially-prepared glass plates and allowed to dry prior to the next step in the process.

1. Soak in water at 4°C. for 1 hour.
2. Soak in developer at 4°C. for 2 hours.
3. Bring plates up to room temperature (20°C.) for ½ hour.
4. Soak in 2% acetic acid stopbath at 4°C. for 1 hour.
5. Soak in fixer at 4°C. for 48-72 hours, or 1½ times the time it takes for the plates to clear.
6. Wash with water at 4°C. for 48-72 hours.
7. Soak in 3% glycerin solution at 4°C. for 12 hours.
8. Remove from glycerin, blot dry, and coat edges with oil.
9. When plates dry, coat edges with nail polish base, cut plates to convenient size.
10. Wipe surface gently with alcohol.
11. Keep in humid atmosphere.

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Step 1 is to allow the gelatin to swell so that in step 2 the developer may diffuse more readily into the emulsion. At 4°C. essentially no development takes place, and all that happens during step 2 is that the emulsion soaks up a quantity of developer, which is used in step 3 to develop it. For step 3 the plates are merely taken from the developer tray and placed on the darkroom bench where they are brought up to room temperature rather quickly by conduction. (An alternative method for bringing the plates up to room temperature quickly and uniformly by utilizing a radio-frequency induction heating unit is being experimented with by the author; (results so far are promising, but inconclusive.) During step 3 all the development takes place. Step 4 is simply to halt the development. Step 5 clears the emulsion of all unexposed silver grains, and step 6 clears the plate of all signs of the fixer. The glycerin soak of step 7 is to "plasticize" the emulsion and make it more resistant to dehydration and peeling. In step 8 the plates are lightly blotted and the edges coated with a light oil, to keep them from drying faster than the main body of emulsion, for if they do, there is a great tendency for them to peel and crack. The tendency to peel is further inhibited in step 9 by coating the edges with nail polish base to hold them down. Step 10 is to dissolve the silver which settles in a thin layer on the surface during the processing, and get rid of it. The plates are stored in a humid atmosphere to keep them pliable, or at least to keep them from drying out completely.

The scanning phase is where the brainwork comes in; it is the most interesting part of the whole business. Binocular microscopes with precision stages and shallow depth of focus lenses are used to examine or "scan" the plates. The binocular vision makes it possible to see in 3-D the tracks you are looking at, and to measure the depth at which the different events take place. Of course, this would be impossible without lenses with very shallow depths of focus besides. The resolution is the property of the lenses that you worry about, not their magnifying power, since the individual grains are about 0.5 microns in diameter. The usual objective for rapid scanning is about a 20X used in conjunction with a 10X or 20X ocular to give a total magnification of from 200X to 400X. For examining a track after finding it with the low power lenses, a 45X or 90X oil-immersion objective is usually used with the same oculars as before. Thus the maximum total magnification is about 1800X. The microscopes have calibrated stages so that tracks may be relocated quickly by taking down their coordinates when first found. The technique of scanning differs slightly depending on what is being sought for. For instance, if the number of negative pions entering the plates is desired, the scanner simply scans rapidly with the low-power objective looking for stars where the incident particle is a pion; one horizontal strip whose width is one field of view is scanned at a time. In this manner a 2″ x 3″ plate may be scanned in a day by an experienced scanner. However, if it is necessary to record all, or almost all, of the events on a plate, it may take an experienced person a month to scan a 2x3 plate. There are three general types of events which may take place in an emulsion: nuclear interactions, decays, and tracks stopping with no event.

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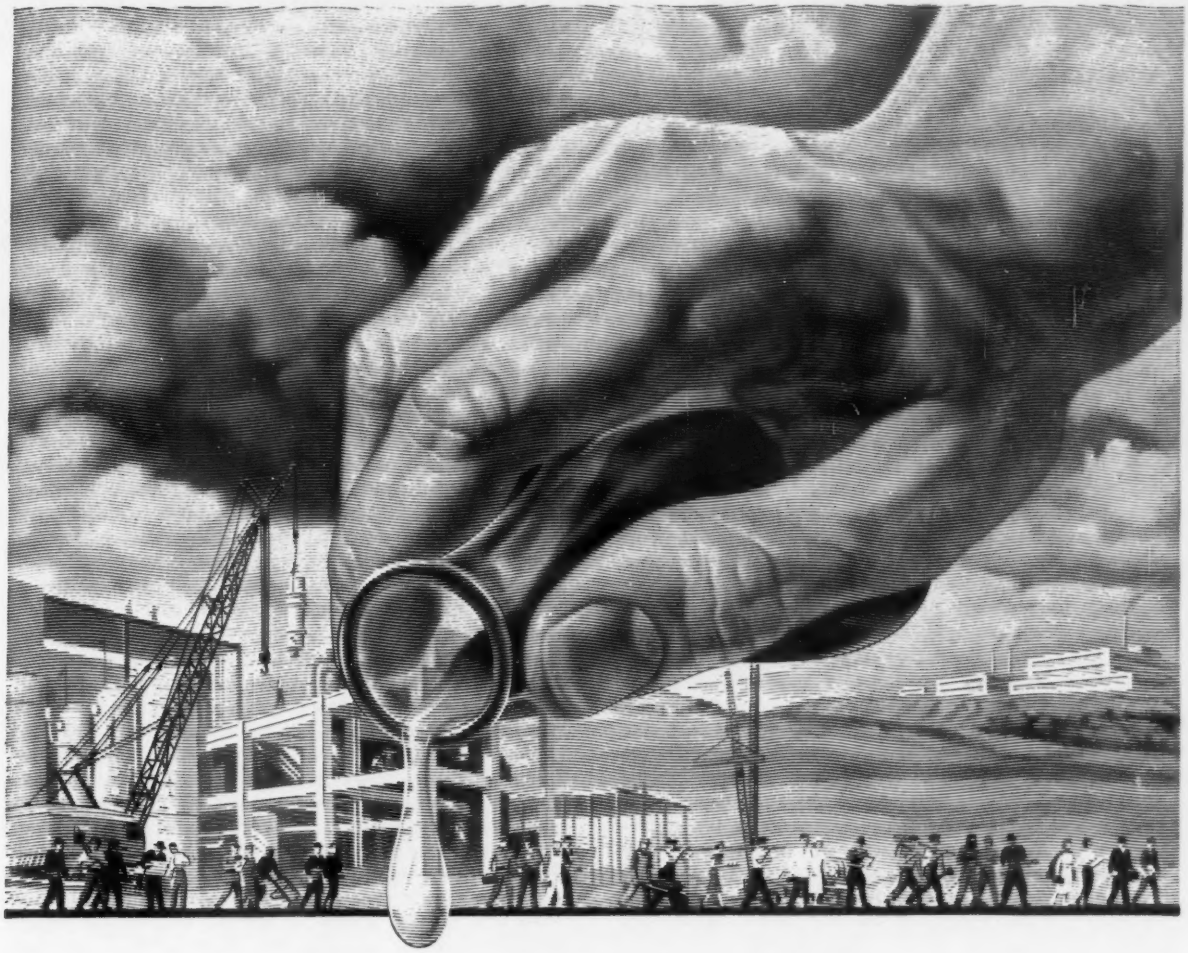
Nuclear interactions ("stars") are characterized by several tracks emanating from one spot in the emulsion. Usually the track of a particle slowing down and falling into the nucleus is evident among them; it is this track that caused the disruption of the nucleus. Sometimes, however, the interaction takes place while the particle is in full flight; in that case, a minimum track will be seen boring straight into the nucleus, from which several protons and mesons may be boiled off. All pions which stop in the emulsion and are negatively charged create stars, hence the above method of counting them.

Decays are characterized by a single track which slows down (i.e., scatters more and more, grain density increases), stops, and emits one or more other particles whose tracks may be seen emanating from the point where the primary stops. The decay of muons and pions may be distinguished by the relative grain densities and scattering; the electron from the muon decay is usually a minimum track, whereas the muon from the pion decay is monoenergetic in the center-of-mass system at an energy such that its track in Ilford G.5 emulsions is 614 microns and it is not minimum. Similar reasoning is used to distinguish K's from pions, etc. A tau decay is a fascinating thing to see, for the primary tau decays into three pions, which can usually be followed until they decay or interact with a nucleus.

The third type of event is a track which just stops in the emulsion with no apparent interaction. This may be due to any one of several things. Any type negative meson could produce a neutron star; i.e., a star in which only neutrons were kicked out of the nucleus, and the neutrons, being neutral, would leave no tracks. Protons and electrons coming to the end of their runs would simply stop in the emulsion since they are not unstable. Occasionally a proton is observed to start and stop inside the emulsion; in this instance a neutron of reasonably high energy has knocked the proton out of a nucleus.

The third and final article in this series will be a description of a typical experiment in the elementary particle physics field.



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the free piston air compressor

by Paul F. Nuclo, '55

The typical free piston air compressor consists of a central two cycle diesel cylinder with two opposed pistons and a combustion chamber between. Each piston is connected, by means of a piston rod, to a larger piston on the end of the same axis. One of these pistons is the air compressor piston which works inside the air compressor cylinder. The other piston is the "bounce" or "cushion" piston which works inside the cushion cylinder. A linkage maintains the synchronism of the two diesel pistons so that they are always in the same position relative to the center of the unit. The basic type of free piston compressor is shown in figure I.

The operation of the typical compressor is as follows: Diesel oil is injected into the central combustion chamber as the diesel pistons approach top dead center. As the oil burns, the pistons are forced apart and air is compressed in the two large cylinders at the ends of the unit. The air from the air compressor cylinder is led to an air receiver. The energy stored in the cushion cylinder plus that of the air trapped in the compressor clearance space forces the diesel pistons back to dead center, compressing the air in the combustion chamber for the next charge of fuel.

The compressor outlined above is a very simple type and has been described merely to introduce the reader to the basic principles of the free piston compressor. Refinements to the basic unit may follow many lines. The most obvious refinement is to replace the bounce piston on the right end by another air compressor piston and place bounce pistons on each end of the unit. The capacity of the compressor can be increased in this way. The bounce pistons may be arranged in any one of four ways:

(1) Outer bounce, outward compression. (Figure II.)

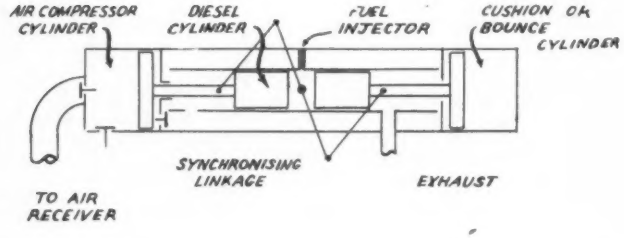


FIG.1 BASIC FREE PISTON COMPRESSOR

(2) Outer bounce, inward compression. (Figure III.)
(3) Inverted bounce, outward compression. (Figure IV.)
(4) Inverted bounce, inward compression. (Figure V.)

In each case it should be remembered that the bounce piston supplies no air to the receiver even though it compresses air in its cylinder. Its only function is to store up energy to return the diesel pistons to top dead center position.
stages as does the Worthington Junkers four stage compressor.

In this compressor air at atmospheric pressure and about 70 degrees F. enters the first stage and leaves at 57 lbs/sq. in. and 230 degrees F. It is then led to a cooler, where its temperature is reduced to 104 degrees F., and then into the second stage. It leaves the second stage at 200 lbs/sq. in. and 200 degrees F. It is then led to a second cooler, where its temperature is reduced to 98 degrees F., and then into the third stage. It leaves the third stage at 690 lbs./sq. in. and 257 degrees F. It is then led to a third cooler, where its temperature is reduced to 83 degrees F., and then into the fourth stage. It leaves the fourth stage at 3000 lbs./sq. in. and 250 degrees F. It is then led to a fourth cooler, where its temperature is reduced to 75 degrees F., and then to the air receiver.

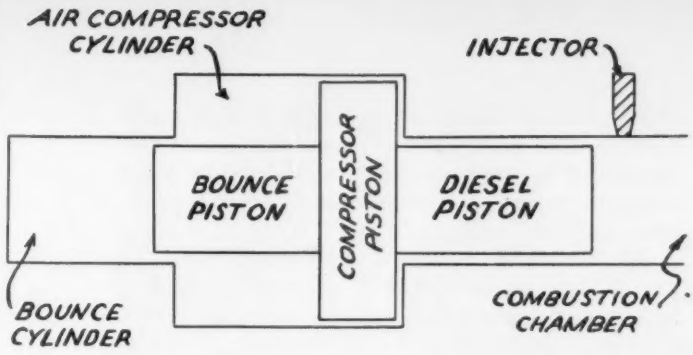
Operating Characteristics of Compressors

(1) Any free piston compressor operates with a variable stroke determined by the amount of fuel burned in the diesel cylinder. Governing usually consists of controlling the stroke until the desired output is reached. A pressure sensitive control varies the rate of fuel injection thus holding the receiver pressure constant for any particular setting.

(2) The energy stored in the cushion cylinder grows larger as the stroke increases. In practice, the design is usually arranged so that the sum of the energies returned by the compressor and cushion cylinders is virtually constant from no load to full load.

(3) Two piston compressors are designed to consist of two masses oscillating in opposite directions, both masses having the same momentum so that the machine transmits to its support only its static weight and no foundation is needed. In the multistage compressor the sum of the momentum forces and the pressure forces is always such to cancel out any horizontal force and no foundation is needed.

The highest output and efficiency of the unit will be obtained by operating it at the highest firing pressure and temperature possible. However,



OUTER BOUNCE OUTWARD COMPRESSION
FIG. 2 (LEFT HAND END)

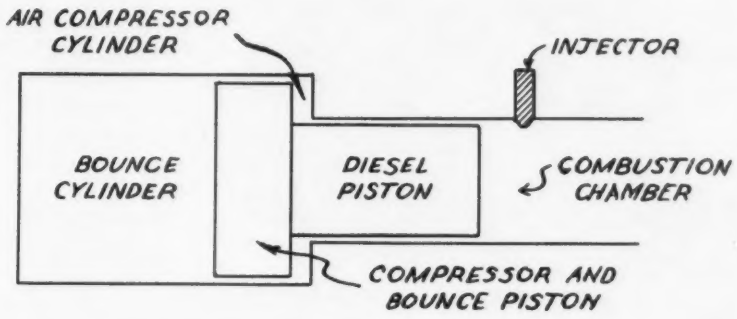


FIG. 3 OUTER BOUNCE INWARD COMPRESSION
(LEFT HAND END)

the greatest factor in the success of the unit is the life of the piston rings and the liners of the combustion cylinder. As the pressure and temperature in the compression cylinder are increased the question of ring and liner wear is greatly aggravated. Some of the possible causes of ring and liner failure follow:

(1) Maximum firing pressure in combustion chamber is excessive.

(2) Maximum rate of pressure rise in the combustion chamber is excessive.

(3) Irregularities on the liner surface scores rings.

(4) Carbon formation on liner and ring grooves causes local hot spots.

(5) Weakening of liner and rings due to excessive temperature.

(6) Insufficient gas pressure behind the piston rings. As the combustion pressure builds up, gas flows into the space behind the rings to force them against the liner and maintain the compression. If the rings fit their grooves too tightly, the pressure behind them will be much lower than the combustion pressure, thus forcing the rings away from the liner, causing bending of the ring and possible failure.

(7) Deficiencies of lubrication. In this connection, it should be noticed that on the inward stroke of the pistons, gas pressure, friction and inertia combine to hold the rings against the bottoms of their grooves. On the outward stroke, gas pressure tries to hold the rings against the bottom of their grooves while friction and inertia exert an opposing force. If there is good lubrication around part of the ring and poor lubrication around other parts, the ring will bear partly on one face of its groove and partly on the other. This will cause severe bending of the ring and it may fail.

Without doubt, the most complicated portions of this otherwise simple unit are the starting and fuel systems.

Starting is accomplished by moving the pistons to their outermost position. This is usually done manually by means of a crank attached to the synchronizing mechanism. Air under pressure is then introduced into the compression cylinders from a starting bank. This forces the pistons inward compressing the air in the combustion chamber. Fuel is then injected into the combustion chamber and the unit begins to operate. On starting, the pressure in the multistage unit are not the designed pressures, therefore there is some end thrust, at times as much as 1450 pounds on the first stroke. However, after the first two or three strokes all

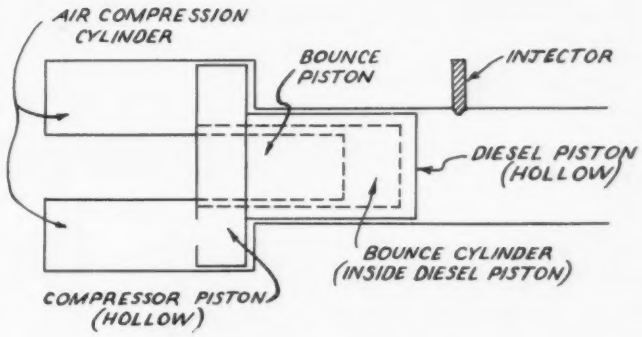


FIG. 4 INVERTED BOUNCE OUTWARD COMPRESSION
(LEFT HAND END)

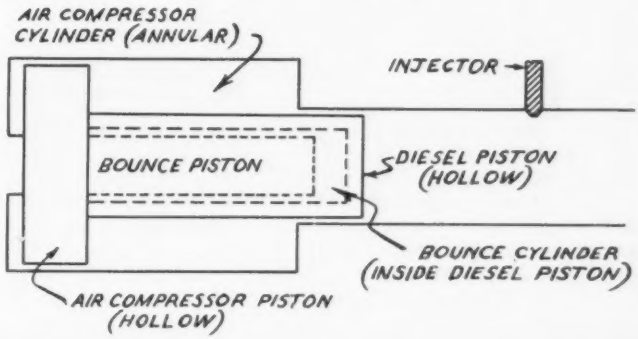


FIG. 5 INVERTED BOUNCE INWARD COMPRESSION
(LEFT HAND END)

stages operate at normal pressure and end thrust and vibration are at a minimum.

To consider the fuel problem it should be pointed out that the fuel pumps as well as other auxiliaries are usually run from the synchronized linkage whose motion is dependent on that of the pistons. However, the piston velocity decreases rapidly at the time fuel injection occurs resulting in a decreasing angular velocity of any cam attached to the linkage. This makes it practically impossible to design a cam with either a constant or increasing rate of plunger rise during the injection time. Two other points are the change of injection time in relation to piston stroke and the accurate metering of quantity of oil injected, neither of which lend themselves well to a mechanism driven from the synchronizing linkage. At first a common rail system was used but this was modified to a rather complicated type of system which gives a definite mechanical control of the quantity of fuel injected and the time of injection.

Although this study is confined to free piston compressors, it may be mentioned that free piston units have been applied to other units. The first of these is the free piston gas generator which is similar to the compressors described before. This generator compresses air up to the supercharging pressure of its motor. Part of the air scavenges the exhaust gases from the combustion cylinder and mixes with them. The remainder is actually used to supercharge the cylinder. The generator produces a mixture of air and exhaust gases at a pressure of between three and five atmospheres and a temperature of about 840 degrees F. This mixture is used to feed a gas turbine. Gas generators of this type have been successful in feeding turbines of 800 to 1000 horsepower with a final net efficiency, all auxiliares included, of 42%.

Another use is to add to the basic compressor a combined steam and gas generator, called a multipressure generator. It is fed with high pressure combustion air from the oscillating free piston compressor. The multipressure generator produces simultaneously steam at high pressure and temperature and combustion gases at a pressure of 26 to 35 atmospheres. The steam is used to run a steam turbine and the combustion gases run a gas turbine.

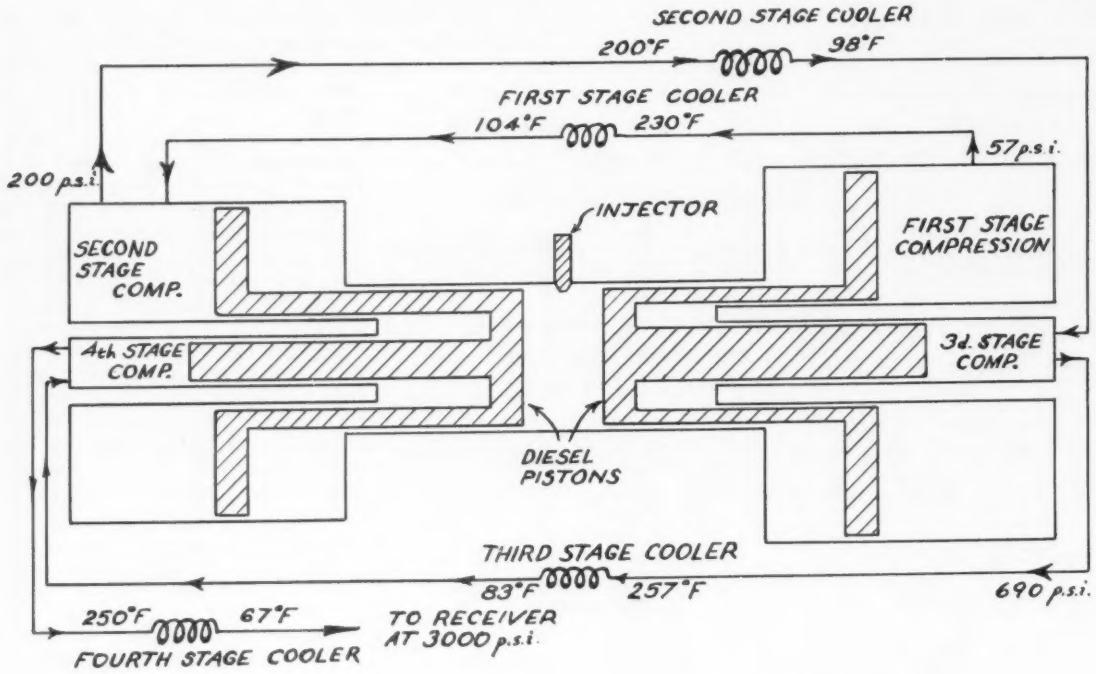


FIG. 6 · WORTHINGTON JUNKERS FOUR STAGE 3000 p.s.i. FREE PISTON COMPRESSOR

As a conclusion it might be best to list the advantages of the free piston air compressor. These are:

(1) Perfect balance with subsequent elimination of vibration and end thrust.

(2) Size and weight is greatly reduced over other compressors of similar capacity, giving an extremely compact and simple unit.

(3) Since there are no crankshafts or connecting rods, side thrust is completely eliminated, giving long ring, piston and cylinder liner life.

(4) Final efficiency of the oscillating supercharged compressor is greatly increased since supercharging and scavenging air remove a large amount of heat from the cylinder walls.

(5) Instantaneous response assures a supply of air at constant pressure at any output.

(6) Fuel economy is very good.

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+2

Mo_6Cl_{12}

Mo_6Br_{12}

+3

$MoCl_3$

K_3MoCl_6

$MoBr_3$

$MoBr_3.3C_5H_5N$

$Mo_4O_3(C_2O_4)_3$

+4

MoO_2

MoS_2

$MoSe_2$

$K_4Mo(CN)_8$

+5

Mo_2O_5

Mo_2S_5

$MoCl_5$

$MoOCl_3$

+6

MoO_3

MoS_3

MoF_6

MoO_2Cl_2

$MoO(OH)_2Cl_2$

$R^*_x(MoO_4)_y$

$(NH_4)_6Mo_7O_{24}$

$(NH_4)_2MoS_4$

K_2MoS_4

$H_3PMo_{12}O_{40}$

$Na_3PMo_{12}O_{40}$

$H_4SiMo_{12}O_{40}$

$Na_4SiMo_{12}O_{40}$

*R= Ag, Ba, Ca, Ce, Co, K, Li, Na, Ni, Pb, Sr, Zn

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CLIMAX MOLYBDENUM

the idea - the machine

by Rae Stiening, '58

No one living today can escape hearing about the giant computers that are being built. These strange machines carry on operations of staggering complexity at tremendous speed. They solve problems that no human in his lifetime could solve; they give answers that have never been known before. They are called *giant brains* by their builders. What are the essential components of these devices? Can we use them for anything other than solving mathematical problems?

An examination of these machines will reveal that they are really combinations of simpler devices, all arranged to give a specific result by a specific method. They reach an answer by a process that has been built into them by human beings. We may, therefore, conclude that even the largest and most complicated man made computing device is nothing but a combination of parts designed to duplicate an idea or process carried on within a human being.

Let us examine several of the basic elements of these machines—the elements expressing the most simple human thoughts. After we understand a few simple circuits, we can put them together to solve a complicated human problem. We may even find that our machine has uses other than that of a computing device.

I shall explain only the "if" circuit in detail. The other idea-machine circuits mentioned can be analyzed by similar methods.

One of the most simple human ideas is the "if" thought. Verbally it can be expressed as follows: if this, then that. Electrically it is expressed as a switch input mechanism, a light bulb output mechanism, and supplementary parts The machine expresses the thought as follows: if the switch is closed, the light lights. The reader can certainly find examples of this thought in everyday life, e. g., if I see a table covered with food, my mouth waters. My eyes are the input mechanism; my salivary glands, the output. It is important to notice that although this idea may apparently be duplicated exactly by the machine, in reality, it is not.

In order to show that the machine is an imperfect copy of the human process I will examine a more complicated "if" idea. The basic reasoning in the game of tic-tac-toe can be stated as the "if" thought. If you take this square, I shall take that one. A machine has been constructed to play this game against a human opponent. However, upon matching wits with the machine, one soon finds that it is not thinking in a human manner. It does not move psychologically or move by what we call intuition. Obviously, it does not react and express ideas like a human at all. Nevertheless, it produces a replica that is satisfactory for most purposes. All the other circuits shown in figure 1 can be classified by the operation which they perform. Similar applications can, no doubt, be found where they may be used individually.

Let us take a human problem and apply machine circuits to solve it. A farmer has a fox, a goose, and a bag of corn which he wants to transport across a river in a boat which will carry only himself and one item at a time. He cannot leave the fox with the goose or the goose with the corn if he wants to complete the journey intact. How would a human being solve this rather interesting though impractical problem? He would probably set up the conditions of the problem in his mind and then proceed to apply trial and error methods until he reached a solution. We will, then, do the same in the machine. Let us first set up the conditions of the problem in electrical circuits. The group of circuits will, when completed, give an output voltage whenever we have performed an operation which does not conform with the conditions of the problem. The farmer is *not* a circuit; trouble can exist only if he is not present. Conversely, the goose is an "if" circuit, for trouble can exist only if she is present. The fox and the bag of corn can be put into an "either or both" connection since either or both of them is/are necessary to cause a disturbance. After we have constructed all the constituent parts of the device, all that is necessary is to connect the individual circuits in series. This arrangement will make them dependent upon one another and will set up the conditions of the problem in the machine. In order to reach a solution our machine would have to contain a memory unit and trial device controlled by the memory. The complete diagram of the conditions unit is shown in figure 2.

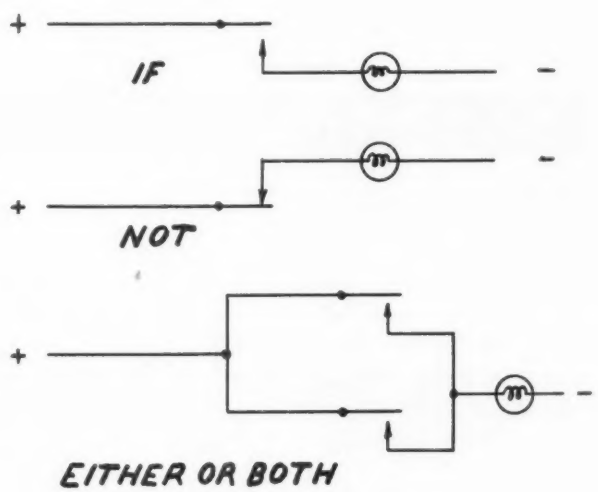


FIG.1 IDEA CIRCUITS SHOWN WITH IDEA NOT EXPRESSED.

Now that we have our machine, we might perform some rather interesting experiments with it. Let us suppose that there is some initial arrangement of the components, fox, goose, etc., which would make a solution very difficult for a human. Let us go further to say that this problem would drive a serious human to insanity. We would classify this insanity as a mental disorder. If we were to set up similar conditions in the machine, we would probably find that it would go insane its own sort of way. We could then analyze the machine's insanity and with this information, we might be able to determine what the problem in the insane human was. Conversely, if we found a problem that disturbed our machine, we could expect that it would disturb a human, too. By the above methods, we should be able to analyze and possibly understand many human mental disorders.

Now that "we know the cause and cure of mental disorders", we might wish to go further and

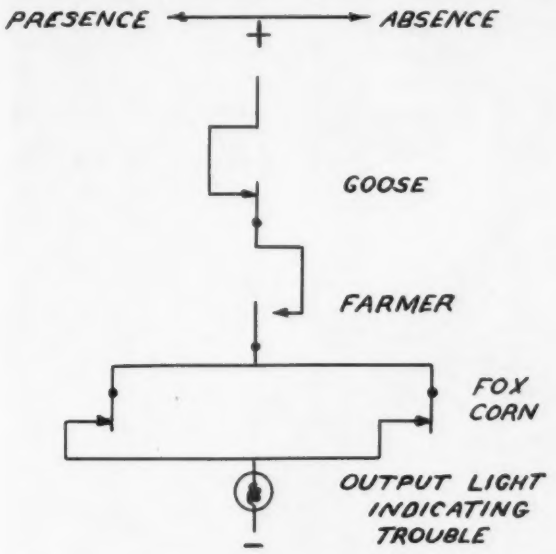


FIG. 2 CONDITIONS FOR FARMER-FOX-CORN--GOOSE PROBLEM. ELEMENTS IN PRESENT POSITIONS.

attempt to determine just how some human processes work. There are obviously limitations on the extent to which a mechanism can analyze itself. Because of this we would expect to have a great deal of trouble if we were to attempt to work with our own thoughts. Having discounted self-observation as a method of solution, we will try another method. If we had a machine which duplicates exactly a human process, we could certainly analyze it. From this we could determine exactly how the human process worked. The problem, therefore, is to build a machine that will act exactly in the same manner as its human counterpart. In reality, we can only approach this condition. The more exactly our machine duplicates the human process, the more exact our results will be.

Let us take a human process and attempt to analyze it. The example will be the associative learning process classified by the Russian psychologist, Pavlov. In Pavlov's experiments, a bell was

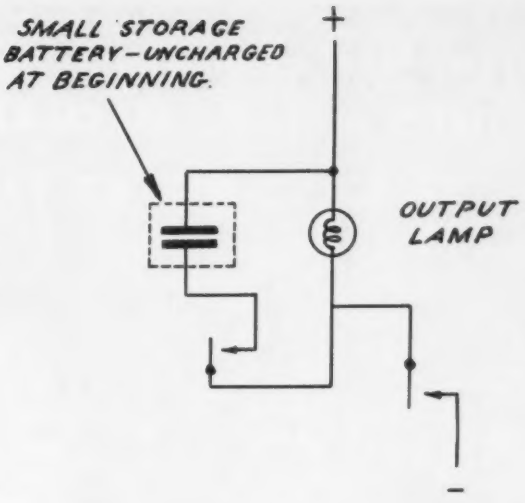
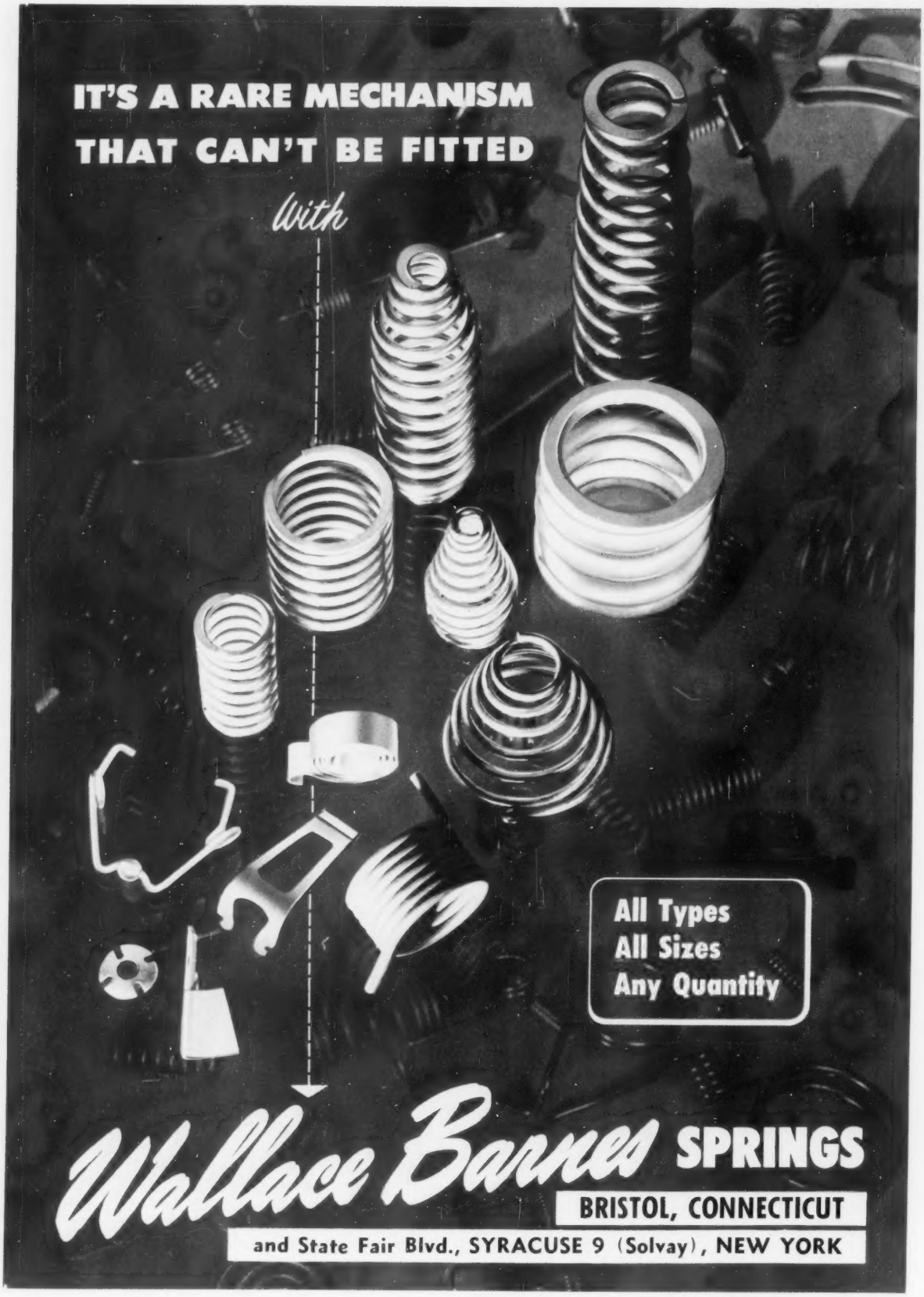


FIG. 3. ASSOCIATIVE LEARNING DEVICE

rung every time that a group of dogs was fed. Pavlov had a device by which he could measure the salivary activity of a dog. After a time he found that the dog's nervous system associated the sound of the bell and the idea of feeding. The sound of the bell alone could produce a salivary reaction. Although we use the dog example, the human process is similar and any conclusions that we draw from the dog's process will be probably valid in humans, also. As our first attempt to duplicate this reaction, let us consider the circuit in figure 3. If button A is pressed, the light lights. If button B is pressed, there is no reaction. If A and B are held down together for a time, the light lights. After a certain period of time, B alone will produce a reaction. Knowing that the machine duplicates the reaction to the extent classified, let us see if we can obtain any additional information from the system. By experiment we find that if we press button B by itself many times after the association of A and B is made the battery will discharge and the reaction will stop. We also know that the strength of the association is an increasing function of time. Pavlov found by experiment that the ringing of the bell alone as a false stimulus, would lose its effect after a time. He also found that the length of time over which the sound of the bell and the feeding process were associated determined the strength of the association. Thus we see that the conclusions which we drew from our machine are verified by observation. Nevertheless, our machine is not an exact copy of the process by any means. The biologist will tell us that our storage battery process does not occur in the human brain. He will explain a parallel nerve reaction as a method of storing information. If we build a new machine according to this data, it would probably be a more exact copy of the animal process. Once we have a machine that responds in exactly the same manner as the animal, we can be reasonably certain that we have duplicated and analyzed the operation of the nervous process.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Electronics Research Engineer Irving Aino records radiation antenna patterns on Lockheed's Radar Range. Twenty-two foot plastic tower in background minimizes ground reflections, approximates free space. Pattern integrator, high gain amplifier, square root amplifier and logarithmic amplifier shown in picture are of Lockheed design.

Jim Hong, Aerodynamics Division head, discusses results of high speed wind tunnel research on drag of straight and delta wing plan forms with Richard Heppe, Aerodynamics Department head (standing), and Aerodynamicist Ronald Richmond (seated right). In addition to its own tunnel, Lockheed is one of the principal shareholders in the Southern California Cooperative Wind Tunnel. It is now being modified for operation at supersonic Mach numbers.

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taconite

by Snooky Klutz, '55

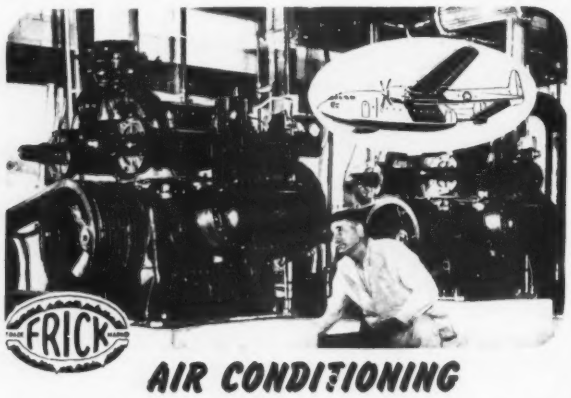
Since 1892, America's iron and steel industry has been removing iron ore from the great iron deposits of Minnesota, a total of about two billion tons or eighty-five per cent of the world's consumption to date. Now only one billion tons of Minnesota's high grade ore (which average fifty-one per cent iron) is left. Since the United States' consumption of iron ore in 1953 was 120 million tons, ninety-six million of which came from the Lake Superior district, it is apparent that these high grade iron reserves are rapidly approaching depletion. But there is no cause to worry over the depletion of our domestic supply of iron since this same district has an enormous amount of low grade iron bearing rock. In the Biwabik iron formation of Minnesota, whence come all Mesabi iron ores, there exists untapped reserves of magnetic taconite, a high silica, low iron content (twenty-five per cent iron, fifty per cent silica) recoverable ore. Along the 100-mile length of the 400-750 feet thick iron formation there is an estimated six billion tons of taconite exploitable through open pit mines and another twenty-one billion tons of ore available from underground mines plus ten billion tons of less desirable, lower grade, but exploitable, taconite.

The method for the recovery of the taconite, that is, the method for preparing the rock to a form which can be fed directly to a blast furnace as can be the high grade iron ores was the main metallurgical stumbling block before the taconite reserves could be tapped. Dr. E. W. Davis of the Mines Experiment Station of the University of Minnesota, who has been working with taconite since 1915, is the person most responsible for the conquering of this problem. He first developed the magnetic separator which separates the crushed magnetic iron from the non magnetic content of the taconite. But the fine magnetic iron powder is unsuitable for the blast furnace since it would blow right out of the flues. First it has to be treated so that the powder coagulates. There are three methods for this. The first mixes a clay binder and pulverized coal with the powder, sends it through a rotating drum which rolls the powder into marble sized pellets and then sends it through a furnace which bakes the pellets into hard porous blast furnace material. The other methods mix limestone with the powder and send the mixture through a rotating kiln which converts the mixture into nodules or send the powder with pulverized coal through a furnace which converts the powder into sinters. The resulting taconite concentrates contain 62.5% iron and 10-12% SiO_2, a richer blast furnace mixture than the direct mining ores. The total concentration process requires three tons of taconite per ton of concentrate, sixty to seventy-five kilowatt-hours of electric power per ton of concentrate, forty tons of water per ton of concentrate, and thirty to forty million dollars of capital investment per million tons annual capacity. It also brings in the problem of what to do with the two thirds of the taconite which is waste material.

Also developed at the Mines Experiment Station was a substitute for a drill since the drill worked very slowly and was quickly worn in the extremely hard taconite. This was the jet piercer, a fifty-foot high, 77,000-pound device fed by kerosene and liquid oxygen that plays a 4,400 degree flame into the ground and shoots water upon the hot rock which forces it to fracture and explode. With this instrument dynamite holes can be "drilled" up to forty feet deep at eighteen feet per hour.

Dr. Davis was also instrumental in talking the Minnesota legislature into taxing the taconite by the amount concentrate produced instead of the amount mined. Once the tax laws were changed, there was nothing to hold back the taconite concentration.

There are three companies which are producing taconite concentrates: Erie Mining Company, (owned by Bethlehem Steel Corporation, Youngstown Sheet and Tube Company, Pickands Mather and Co. of Cleveland and the Steel Co. of Can-



AIR CONDITIONING

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ada, Ltd.), Reserve Mining Co. (owned by Republic Steel Corporation and Armco Steel Corp.) and the Oliver Mining Division of U. S. Steel.

Erie was the first concentrate producer, turning out 200,000 tons of pellets per year at its Aurora, Minnesota plant. In 1953 it started a 300 million dollar project which will be completed in 1957 which will expand the concentrating facilities, build a seventy-five mile railway to Two Islands Harbor on Lake Superior and increase its capacity to 7.5 million tons of concentrate per year, with a possible expansion to 10 million tons per year.

Reserve Mining Co. started producing in June 1952 at Babbitt, Minnesota, where a premature taconite concentrating plant had been abandoned thirty-two years ago. It now has a capacity of 300,000 tons of pellets per year and is expanding with a $180 million project which includes a forty-eight-mile railway from its Babbitt reserves at 1.5 billion tons of taconite to its new plant, the one-third mile long Davis Works, and harbor at Silver Bay, Minnesota, on Lake Superior. Initial capacity this year will be 3.75 million tons of concentrate with a possible ultimate expansion to ten million tons per year.

Oliver Iron Mining Division has two plants in Minnesota, at Mountain Iron and nearby Virginia where 550,000 tons of nodules and sinters are produced per year. They intend eventually to expand capacity to ten million tons per year.

By 1970, these three companies should be producing thirty million tons of concentrate per year, one-fourth of the United States present consumption.

One other company has been working with low grade iron deposits. The Humboldt Mining Co. (owned by Ford Motor Co. and the Cleveland Cliffs Iron Co.) are concentrating nonmagnetic jasper by flotation and heavy media separation. Two plants are planned, one with a capacity of 200,000 tons of concentrate per year, and the other with a capacity of 400,000 tons per year with a possible eventual capacity of 1.5 million tons per year.

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A few figures tell the story.

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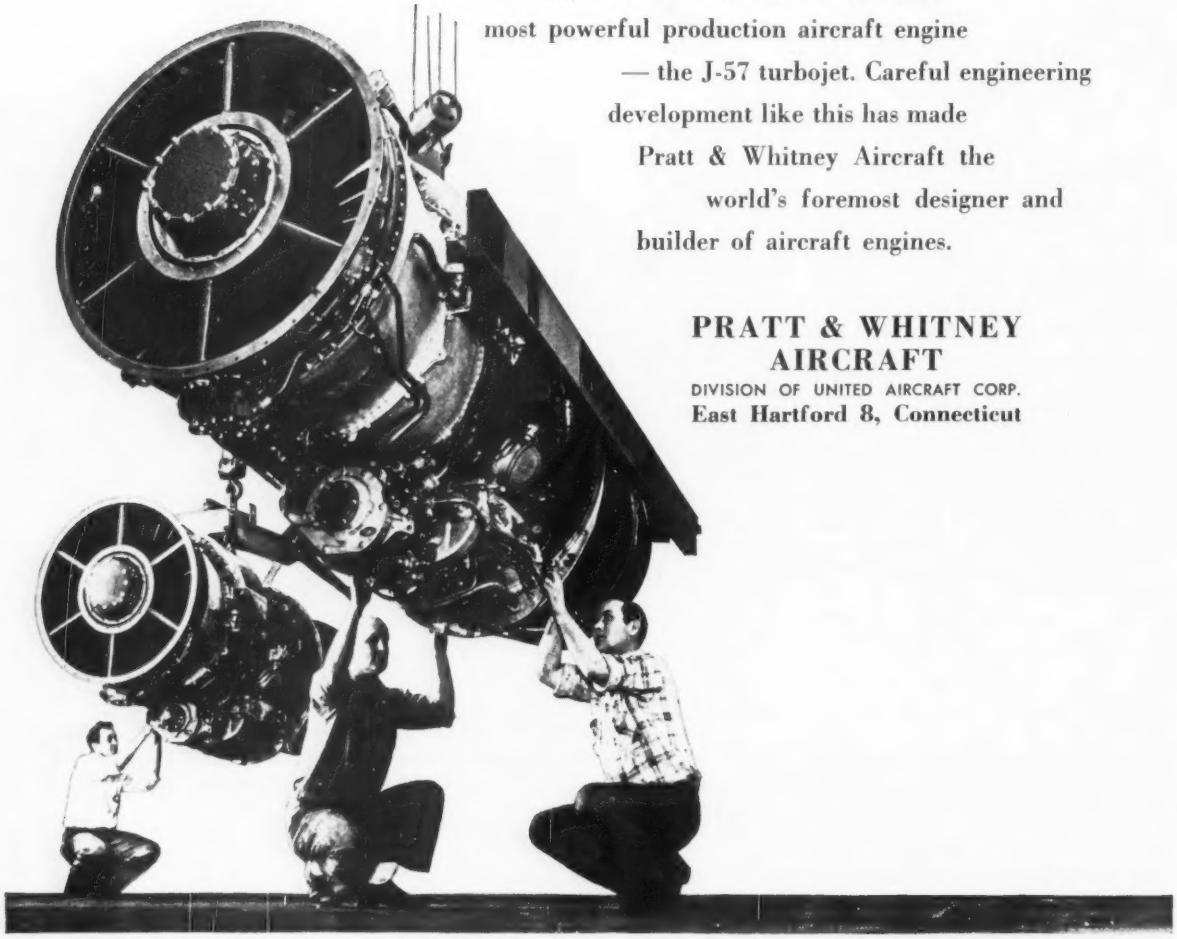
. . . 14,200 hours of experimental engine operation in test cells and in flight test.

. . . 4,000,000 individual, complex mathematical problems solved by electronic computers.

As a result, America now has the world's most powerful production aircraft engine — the J-57 turbojet. Careful engineering development like this has made Pratt & Whitney Aircraft the world's foremost designer and builder of aircraft engines.



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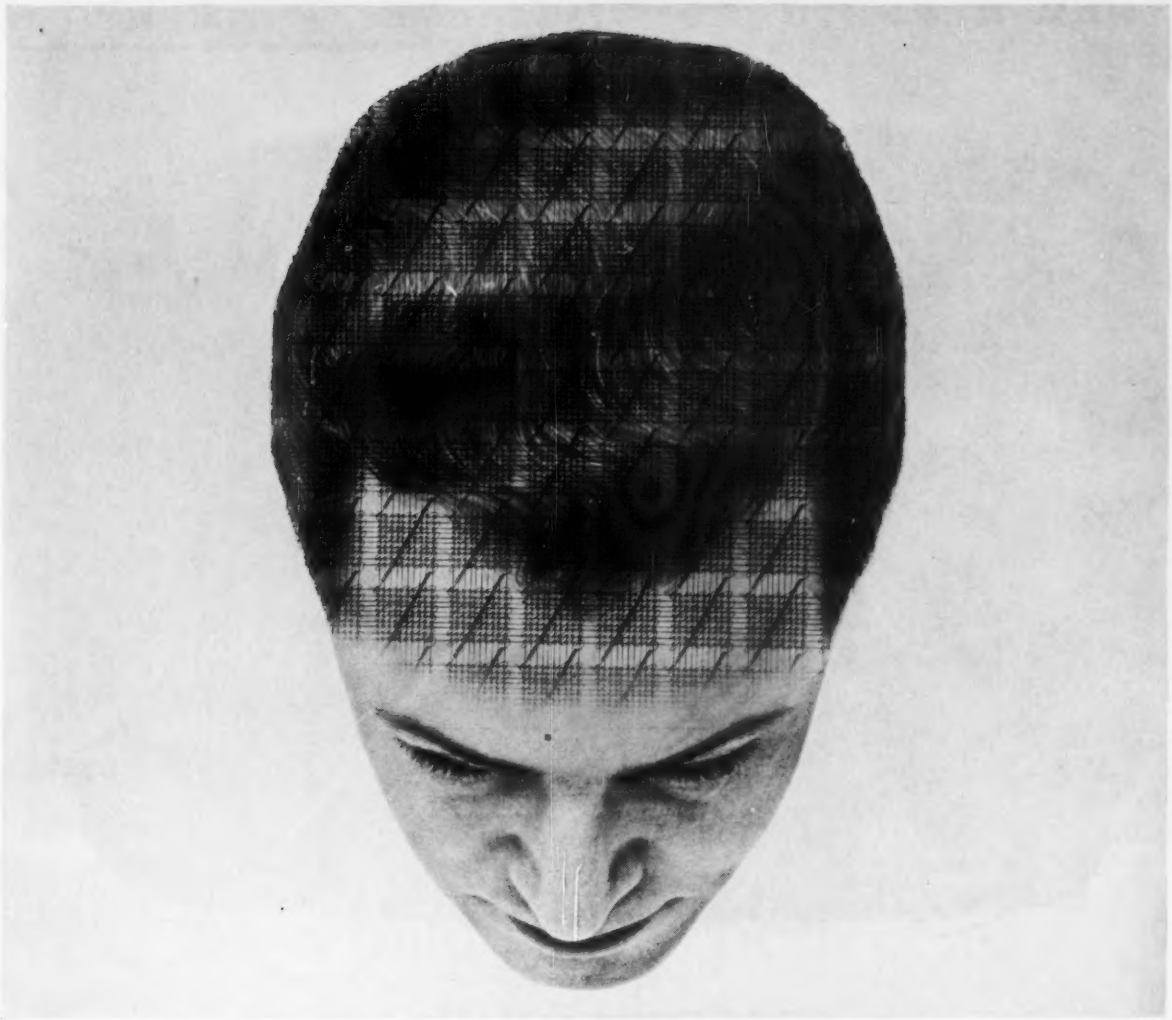

Superimposed over this man's head is the matrix (or heart) of RCA Electronic "Memory." See description below.

New RCA Magnetic "Memory" recalls thousands of facts in a fraction of a second

Each dot you see in the squares above is actually a magnetic "doughnut" so tiny that it barely slides over a needle point. Despite its size, however, each "doughnut" stores away one bit of information for future reference. And 10,000 of them fit on a framework smaller than the size of this page!

Here are the cells of the RCA magnetic "memory" that is the key element in virtually all high-speed electronic computers. The greatest significance of this "memory" is its ability to deliver, in a few millionths of a second, any information it holds.

Almost instantly, an insurance company can process a claim. Just as fast, a manufacturer with inventories spread around the country can determine what products are making money—and *where*.

With such "memories," electronic computers predict accurately the next day's weather for the nation, using data on atmospheric pressure, temperature, and wind velocity from every part of the United States.

The leadership in electronics that created this man-made RCA "memory" is responsible for one achievement after another in television, radio, radar and other RCA products.

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Each time the wheels turned, a bean dropped to a container below the axle. Then Leonardo counted the beans and multiplied by the wheel circumference to learn how far he'd walked.

Even New Departure ball bearings couldn't do much for Leonardo's simple pedometer. But if Leonardo were designing one of today's complex instruments, he'd call on New Departure for ball bearings. That's because New Departures bring about such advantages as low starting torque and even lower running friction, precise location of moving parts at all speeds, compact design, long life with almost no upkeep. Besides, New Departure's research and manufacturing facilities are unmatched.

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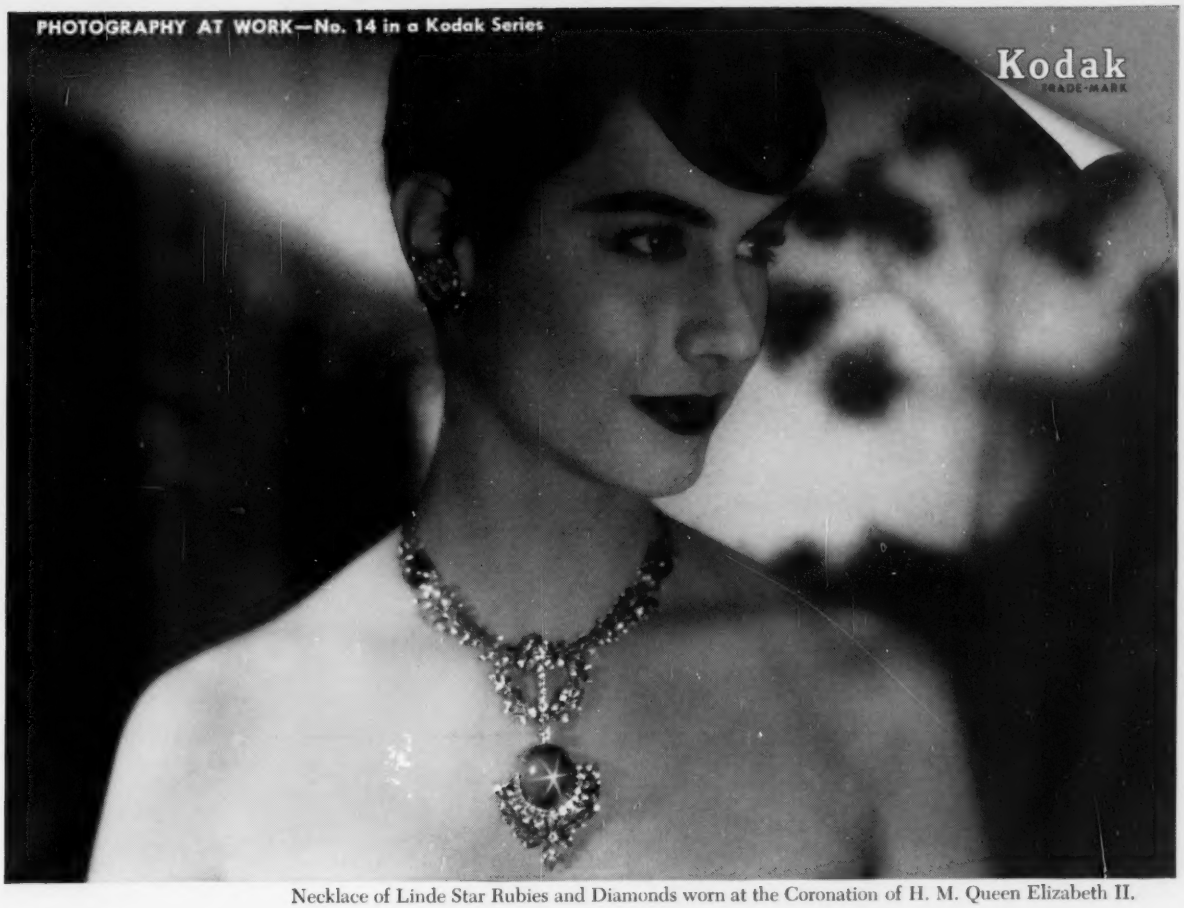
Automatic gram-centimeter torque tester measures starting torque characteristics of New Departure instrument ball bearings. Like many of the ultra-precise devices used in bearing manufacture, this torque tester was largely developed by New Departure.



Necklace of Linde Star Rubies and Diamonds worn at the Coronation of H. M. Queen Elizabeth II.

Man-made gems perfect as nature's finest—

created with the aid of photography's keen eye

Linde Air Products Company measures rare elements as close as 2 parts in a million with the spectrograph to produce star sapphires and star rubies more nearly perfect than natural gems.

Wartime instruments called for millions of synthetic jewel bearings. But supplies from Europe were shut off. So at Uncle Sam's request, Linde, a division of Union Carbide and Carbon Corporation, undertook to create sapphires and rubies—with photography filling a role in the intricate technology.

Postwar, Linde went even further. Using the spectrograph, a photographic instrument so sensitive it can measure the chemical content of celestial bodies, they found just the right trace of rare element to create a deep silky star within the stone and thus achieved the fabulous Linde "Stars"—man-made counterparts of one of nature's rarest gems.

This is the way photography is working in small companies and large, in laboratories, on production lines, in offices and drafting rooms. It is saving time, reducing error, cutting costs, improving production for all kinds of business and industry.

Graduates in the physical sciences and in engineering find photography an increasingly valuable tool in their new occupations. Its expanding use has created many challenging opportunities at Kodak, especially in the development of chemical processes and the design of precision mechanical-electronic equipment. If you are a recent graduate or a qualified returning serviceman, and are interested in these opportunities, write to Business & Technical Personnel Dept., Eastman Kodak Company, Rochester 4, N. Y.

Eastman Kodak Company, Rochester 4, N. Y.

How will you help to sharpen radar's "eyes"?

Exact range and accuracy of the radar antennas shown here are classified. But this can be told—the radio energy transmitted can light fluorescent lamps 100 feet away.

Progress in radar, as in the entire field of electronics, has been rapid. At General Electric much credit for these advances belongs to engineers who are recent college graduates. Take, for example, E. B. Carrillo, EE, Pratt Institute, '49, responsible for manufacture of servo- and time-sharing systems, and G. G. Wilson, EE, N. Y. U., '48, in charge of design and development of remote control equipment.

The work of these young men typifies GE's emphasis on young, creative engineers from such fields as electrical, mechanical, metallurgical and aeronautical engineering, and from the scientific fields of physics and chemistry. Like other graduates, Carrillo and Wilson were able to increase their engineering awareness in the after-graduation G-E program of technical assignments. In this program, the engineer selects the fields, the locations himself. And at G.E. you will be able to make real contributions early in your career in activities ranging from plastics to large electrical apparatus, electronics to jet propulsion, automation components to atomic power.

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